

Trunk posture exposure as a risk factor for low back disorders in farmers

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Abstract

Introduction

Low back disorders (LBD) are the most prevalent type of musculoskeletal disorder in farm worker. Farm workers have a unique employment context with physical tasks that may expose them to awkward posture, but the link between exposure and LBD has never been summarized. The objectives of this thesis were to: 1) conduct a systematic literature review on trunk posture as a risk factor for LBD in farmers; and 2) measure the patterns of trunk posture exposure in Saskatchewan farm workers.

Methods

Objective 1: Comprehensive electronic searches were conducted in six data bases with two conceptual groups of search terms: ‘farming’ and ‘LBD.’ Screening, data extraction, and risk of bias assessment were performed by two reviewers independently.

Objective-2: A one-year field-based study with three repeated farm visits directly measured working posture for 49 farm workers (91 measurements total). Individual and farm characteristics were obtained via questionnaire. Trunk posture angles and velocity were measured with motion-tracking inertial sensors and summarized as 10th, 50th, and 90th percentile and time spent in neutral or extreme postures. Work tasks on farms were categorized in to driving, manual, and mixed activities. The variability between the farms tasks was analyzed with Generalized Estimation Equations (GEE).

Results

Objective 1: Out of 1394 titles identified in the search, nine articles met the inclusion criteria. The included studies were diverse in terms of employment context, region, and commodity; all used self-report to measure exposure. Two studies showed no association, one showed a protective effect, and six showed a positive association between awkward working posture and LBD in farm workers (OR from 1.3 to 3). Despite the diversity, the weight of evidence supports a relationship between awkward posture and LBD.

Objective-2: The 90th percentile trunk flexion-extension angle was significantly higher for manual as compared to driving tasks, and the 90th percentile flexion-extension velocities were also significantly higher for manual than driving tasks. Participants spent 38% of their working time in trunk forward flexion $\geq 20^\circ$, which according to previous epidemiological studies may increase their risk for LBD.

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Dedication

This thesis is dedicated to my beloved wife Fouzia Idrees, who loves and encourages me all the time without reservation. Thank you also to my kids Muhammad Saad Idrees, Rameen Idrees, and Maaz Khan and to everyone who supported me.

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List of Abbreviations

LBD: Low Back Disorders

MSD: Musculoskeletal Disorder

ROB: Risk of Bias Assessment

OR: Odds Ratio

PR: Prevalence Ratio

CI: Confidence Interval

CLBP: Chronic Low Back Pain

SD: Standard Deviation

SNQ: Standardized Nordic Questionnaire

IMU: Inertial Measurement Unit

WBV: Whole Body Vibration

Hz: Hertz

GEE: Generalized Estimation Equation

SPSS: Statistical Package for Social Sciences

ATV: All Terrain Vehicles

BMI: Body Mass Index

IQR: Interquartile Range

Chapter-1: Introduction

1.1 - Background and Introduction

Chapter one provides a general introduction to low back disorders (LBD) prevalence and the economic burden on society. This chapter also provides an overview of LBD in the agriculture industry, LBD risk factors in farm workers, trunk posture as a risk factor for LBD, and exposure assessment methods to measure trunk posture. Finally, this chapter presents the significance and research objectives of the thesis.

1.2- Low back disorders burden on society

1.2-1 LBD Prevalence and Cost

LBD are an expensive and prevalent public health problem in the general population (1). LBD are among the most common health problems, and also the most common cause of disability in both high- and low-income nations (2–6). The lifetime prevalence of LBD in developed high-income nations is estimated to be above 85% (6,7). Worldwide lifetime prevalence is estimated to be around 39%, while the point prevalence is approximately 19% (6). In Canada, LBD affect 85% of the working population (8) and up to of 70% to 80% of people will experience back pain at some time in their life (9). The annual reported back disorder prevalence ranges from 15% to 45% with a point prevalence of approximately 30% (9). Over 80% of Americans will suffer from at least one episode of back pain in their lifetime (10). Because of the high prevalence, LBD contribute to a substantial economic, societal, and public health cost to society. LBD incur billions of dollars for medical expenditure annually, and this economic burden is an important concern for low-income nations as well as for high-income nations (7). LBD substantially impact working populations and may be associated with high levels of disability and restriction in daily activities and participation, including inability to work, sick leave, and early retirement (5,6).

The treatment of LBD represents a substantial cost to society (7,11,12). The estimated cost of back pain in the United States exceeds \$100 billion per year; two-thirds of these costs are indirect due to lost wages and reduction in productivity (13). LBD are one of the most common reasons for visiting a physician (12,14,15), and Canadians with LBD utilize significantly more healthcare resources than those without LBD (9,15). Individuals with back pain have 60% higher healthcare expenditures as compared to without back pain (10). Notably, in 2014 Canadian medical expenditures for LBD were estimated to be between \$6 and \$12 billion annually (16). In the USA, back pain is the most common cause of activity limitation in people younger than 45 years of age (9), the second most frequent cause of physician visits in Canada (15), and the third most common cause for surgical procedures (9).

1.2-2 LBD and Work-related disability

Globally LBD cause more years lost to disability than nearly 300 other conditions studied, and sixth in terms of disability adjusted life years (DALYs) (17). In the United States back pain is the most common cause for filing an insurance claim, workers' compensation claims, or sick leave (13). It accounts for about one-fourth of all claims and one-third for all compensation cost (13). Data from National Health Interview Survey report 22.4 million low back pain cases (prevalence 17.6%) for a given one-year period; these cases resulted in approximately 149 million lost work days (13). Twenty-one percent of workers reported 3-5 day's absence from work (18), 14.3% lost 6-10 days of work, and 29.6% reported 3 or more weeks away from work (19).

In Canada, workers' compensation claims are administered by each province separately so national data can be difficult to get, but investigation by province shows back pain to be an economic burden nationally. According to the Worker's Compensation Board of Saskatchewan in 2010, 28.3% of all time-loss claims were related to the back (5,716 claims), and the total cost of back-related claims was

\$54 million dollars (20). Work Safe BC reported more than 107,000 claims for back injuries in the period from 2000 to 2004, which is about 25% of all worker's compensation claims in British Columbia (16).

1.3- Low back disorders in agriculture

LBD are a prevalent health problem among various occupational groups (21). Agriculture, mining, fishing, forestry, and construction are ranked as high-risk industrial sectors for LBD (22). Low back disorder is a major occupational health problem facing the agriculture workforce globally (10) with a one-year prevalence of 57% (23), much higher than the 15% to 45% reported in the general population (9). According to a recent systematic review on musculoskeletal disorders (MSD) among farmers (23), pooled lifetime low back pain prevalence was 75% and pooled 1-year prevalence was 47.8%. The review authors identified low back pain as the most prevalent MSD in farmers (24). Rosecrance et al studied MSD in Kansas farm workers and found that the low back was the most commonly reported painful anatomical area; they found agricultural workers have twice the risk of low back pain as compared to the general working population, and are eight times more likely to change their work activities because of low back pain (19).

The International Labour Organization (ILO) Programme on Occupational Health and Safety reported that “agriculture is one of the most hazardous occupations worldwide.” Furthermore, the National Institute for Occupational Safety and Health has identified agriculture as a “National Occupational Research Agenda priority industry” for research and prevention efforts (10). Notably, farmers with low back pain experience high healthcare costs and loss of productivity (10,19). Farming requires targeted investigation, as it is a unique sector with different employment contexts and work scheduling than other occupations. Farmers usually start working at very young age and often continue to work long after typical retirement age (24). The Agriculture Census performed by

Statistic Canada 2011, approximately 52.7% of Canadian farm operators work more than 40 hours per week on their farm and 48.4% of farm operators also work off the farm (25). According to the Statistics Canada 2011 Census of Agriculture, there are 36,952 farms operating in Saskatchewan (25). These farms produce diverse commodities such as canola, grains, alfalfa, chickpea, oil seeds, pulses, poultry, dairy, pork, and beef (25). Farmers producing these commodities perform many physical work tasks such as: operating harvesting machinery, equipment use, planting, facilities maintenance, and animal care (19,24). The nature of work exposures and their cumulative effect are likely to be different among farmers than in other occupations, but research has not yet been synthesized for this industry. An in-depth understanding of pain patterns, exposure to risk factors, and LBD-related disability would help to address the knowledge gaps within this population and help inform prevention strategies to address the persistently high LBD prevalence and associated costs.

1.4- Risk factors for low back disorders

1.4-1 Personal risk factors

Personal characteristics such as age, gender, body mass, height, sleeping less than 8 hours or low-quality sleep, geographic location (26), alcohol (27), smoking (28), heredity/genetics, low educational level and weight (29) are considered as personal risk factors for development of LBD. Hamberg-van Reen et al. identified several personal risk factors (i.e. age, smoking, body physical capacity, and body weight) that were positively associated with low back pain (30). Heuch et al. found a positive association between body mass index (BMI) and risk of developing chronic LBP (31).

1.4-2 Psychosocial risk factors

Psychosocial risk factors such as low social support (32), economic loss, low job satisfaction, depression (33), feeling stressed, and work pressure are also contributing factors for LBD (34). Additional psychosocial risk factors such as job dissatisfaction, high quantitative job demands, low rewards, working without breaks, high work demand or mental pressure, lack of autonomy, low job control, low job clarity, low social support, income, disability, and family pressure are also related to increased risk of LBD (35–37). A systematic review on LBD risk factors conducted by Linton et al. found that specific work-related psychosocial risk factors (stress, social support, job control, job dissatisfaction, role conflict, and income) are associated with LBD (37).

1.4-3 Potential work related risk factors for LBD in farm workers

Farm work includes many physically demanding work tasks, usually in combination with high postural load, manual material handling, and application of muscular force (38,39). Common physical hazards which can affect farmers include: lifting, working with the trunk in awkward positions, carrying heavy loads, repetitive jobs for long periods of time, long exposure to whole body vibration from vehicles (e.g. tractors), high workload, risk of fall and trips, and unpredictable action of livestock (40,41). A more detailed discussion of trunk posture as a risk factor for LBD is discussed in the next section; other physical risk factors will be described here in brief.

Chen et al. found the occurrence of LBD is associated with physical work-related risk factors such as pushing, pulling, carrying, lifting, whole body vibrations, and awkward trunk postures (42). Despite this evidence, some authors have argued that physical risk factors associated with LBD have weak and insufficient evidence due to the absence of sufficiently quantified physical work-load in prospective studies (43). In reviews of epidemiological studies on LBD, several physical workload factors have been identified as risk factors (41,44). Manual material handling includes lifting,

pushing, moving, carrying, and pulling of heavy, bulky, or irregular objects during work tasks and can lead to back and other musculoskeletal disorders (45). Forceful movements, working overhead, kneeling, squatting, repetitively bending the back forward, and reaching can place a substantial physical demand on the body, particularly the back (45). NOISH performed a critical review of evidence for work-related MSD in 1997 and found a significant association between heavy physical work and awkward postures with low back disorders (OR 2.2 to 11.0) (46). Seidler et al. suggested in their study of “cumulative occupational exposure to lifting or carrying and to working postures with extreme forward bending” that “the combination of occupational lifting, trunk flexion and duration of the activities significantly increased the risk of low back disorder”(47).

1.5 - Trunk posture as risk factor for low back disorders

1.5.1 Biomechanical factors and low back disorders

Despite the limited information on the specific etiology of LBD, several models have been developed to explain the mechanism for development of LBD (48,49). All of these models assume that exposure to physical load in the workplace (e.g., lifting, trunk flexion, bending) leads to increased mechanical load on the lower back, and that these mechanical loads lead to compression and shear forces on the lumbar spine (Figure 1). These mechanical loads may result in damage to the structures of the spine which may contribute to LBD (50). Therefore, knowledge about exposure to mechanical loads may provide important etiological information for LBD. Investigation of postural exposures such as lifting, twisting, and bending in measurement dimensions such as duration, frequency, and level/intensity provides more nuanced information about mechanical loads influencing spinal structures (49,51,52) (Figure 1).

Howarth, Callaghan and Wang et al. suggested two mechanisms for threshold failure of spinal structures (53,54). The first mechanism assumes damage of spinal structures (e.g. spinal end-plates)

due to the acute high loads which cause direct tissue failure (54). Either a single supra-maximal compression or repeated sub-maximal compression may lead to back injury (55). The second mechanism (repeated submaximal compression) supposes that accumulation of micro-damage or cumulative trauma of the spine leads to decreased tolerance of spine tissues and ultimately leads to spine tissue failure after continued and repeated loadings, which in turn results in the development of LBD (56).

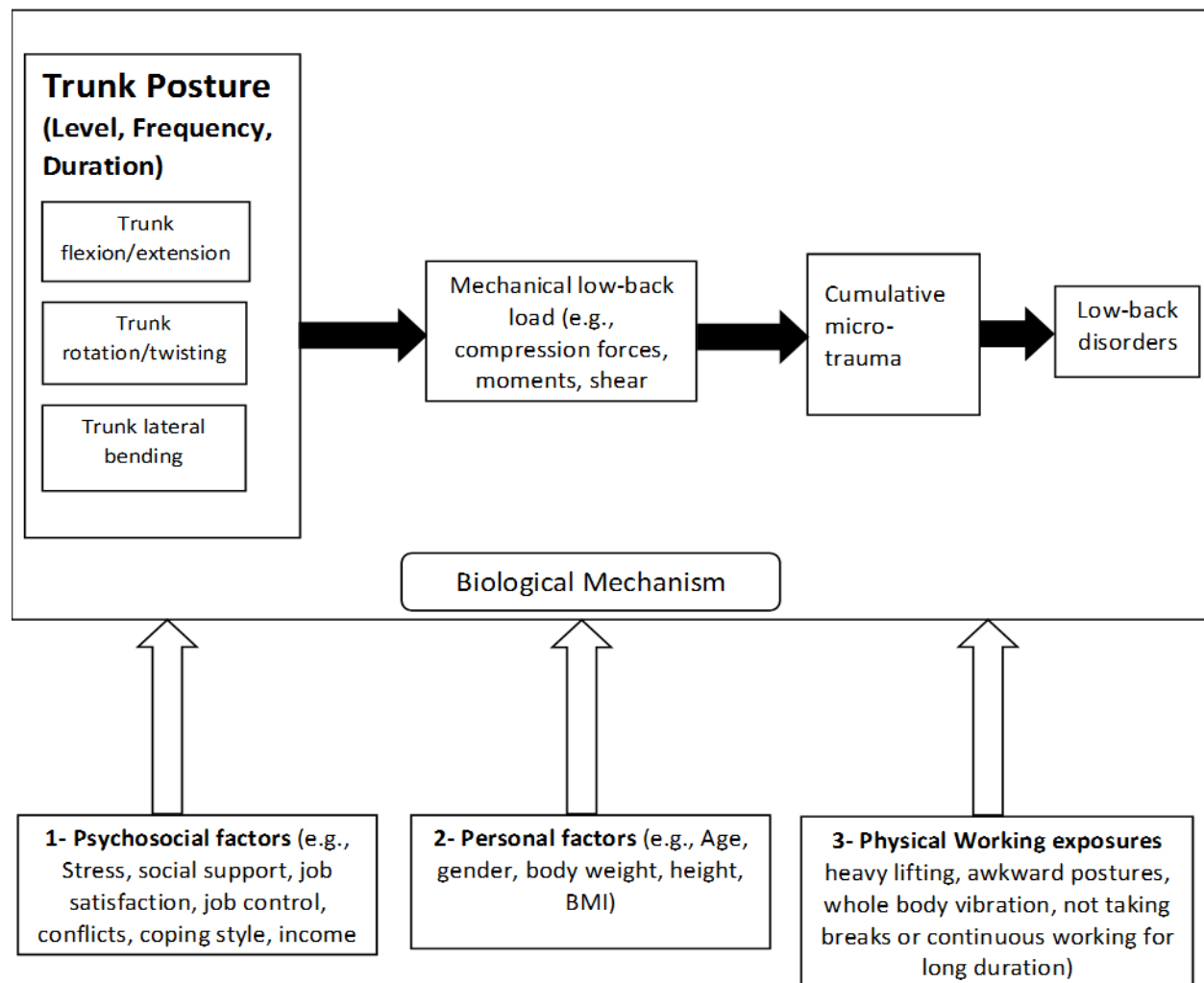


Figure 1.1. Model representing the association of biomechanical matrix with physical workloads/postures, psychosocial, personal, work factors with LBD (57).

1.5.2 Awkward Posture and Low Back Disorders

Although many physical exposures can contribute to LBD, awkward posture may be the most ubiquitous. Occupational posture refers to the working positions that a worker assumes to perform a task or job. Neutral body posture (i.e. anatomical position) is associated with reduced strain on muscles and joints (37). Any posture in which the body moves out of the neutral body posture is considered to be 'awkward posture' (37). Awkward posture can include stooping or bending, looking upward to overhead, reaching above shoulder heights, and can result from body positioning to fit in a tight location, shape of tools and equipment, and poor visual environment that can prevent the worker from maintaining neutral posture of the spine or limbs. Awkward postures force muscles to work harder and can stress other structures such as ligaments and discs (45,47).

Sustained and repetitive trunk bending have been considered as risk factors for LBD (58).

Cumulative load on low back can cause neuro-mechanical changes such as, ligament inflammation, injury of spinal tissues, altered spinal muscle reflex-response, increased lumbar instability, and reduced postural awareness (59,60). The cumulative effect of postural exposure is dependent on the level (i.e. degree of bending), duration, and frequency in which postures are adopted. The interaction between these three domains leads to an exponential decrease of tissue load-tolerance over time (61). One of the challenges to design and improve prevention strategies is to identify threshold limits for cumulative postural exposure within each of the three postural domains for trunk postures (i.e. intensity, frequency, and duration) (62). The effect of posture can be severe if applying force continually in an awkward position (such as lifting while stooped over or a strong grip in a bent position) or maintaining one position for a long period and repeatedly moving in an awkward position (45).

A review conducted by Bernard et al. found a positive association between LBD and work-related awkward posture (36). They found several studies with moderately high levels of association (e.g. odds ratio of 2.29, 95% CI 1.22-4.29) and dose-response relationships between exposure (awkward posture) and an outcome of LBD (63). A review conducted by Marras et al. found moderate evidence for risk of association between awkward posture and LBD. However, there are also several studies that argued that the association between awkward posture and LBD is weaker (43), and none of these reviews have focused on the unique exposure context of farming.

LBD causes significant morbidity, disability, and economic loss among workers. Agriculture workers handle heavy objects, often in awkward posture; however, the risk factors associated with LBD are not well studied (64). Farmers may perceive awkward posture and work related problems (i.e. busy and long working hours, heavy workloads, fatigue, monotonous and repetitive work, and poor working conditions) as unavoidable consequences of farming activities (65). However, these risk factors can be prevented by simple and inexpensive modifications to work tasks (65). Although farmers working with awkward trunk postures seem to be at higher risk for LBD, the evidence for this relationship has never been synthesized. Further information is needed on the unique exposure patterns among farmers to understand the relationship and target prevention efforts.

1.5-2 Exposure assessment for trunk posture

Although accurate exposure assessment is necessary for high-quality epidemiological studies, it can be tricky to achieve. There are three general methods to evaluate physical exposures like trunk posture: 1) self-report, 2) observation methods, and 3) direct technical measurements (figure-2) (66,67). These three methods of exposure assessment are listed in order of improving accuracy (51). Self-report can study a large number of participants at a very low cost and can also collect information about a variety of different exposure variables. Self-reported data can be obtained

through questionnaires, diaries, or interviews (32). Data with observation methods can be obtained through observations at the workplace or through video analysis (51). Direct measurement, though highly precise, is costly and can only provide information regarding the recording or working period. Direct measurement also has low capacity, versatility, and is less generalizable. Self-report may seem to be a more practical tool in large-scale epidemiological studies (67), but some studies show low validity and reliability for self-report and observation measurement methods (68,69). Although more precise, direct measurement methods are expensive compared to self-report and observation methods due to equipment and monitoring costs. Although direct measurement approaches require a longer time for data collection, they are more reliable and valid as compared to other methods (67). In farming occupations, very few field-based studies have assessed ergonomic exposure with direct measurement methods due to logistical challenges and high costs (70). Therefore, there is a gap in knowledge about detailed postural exposure patterns in this industry.

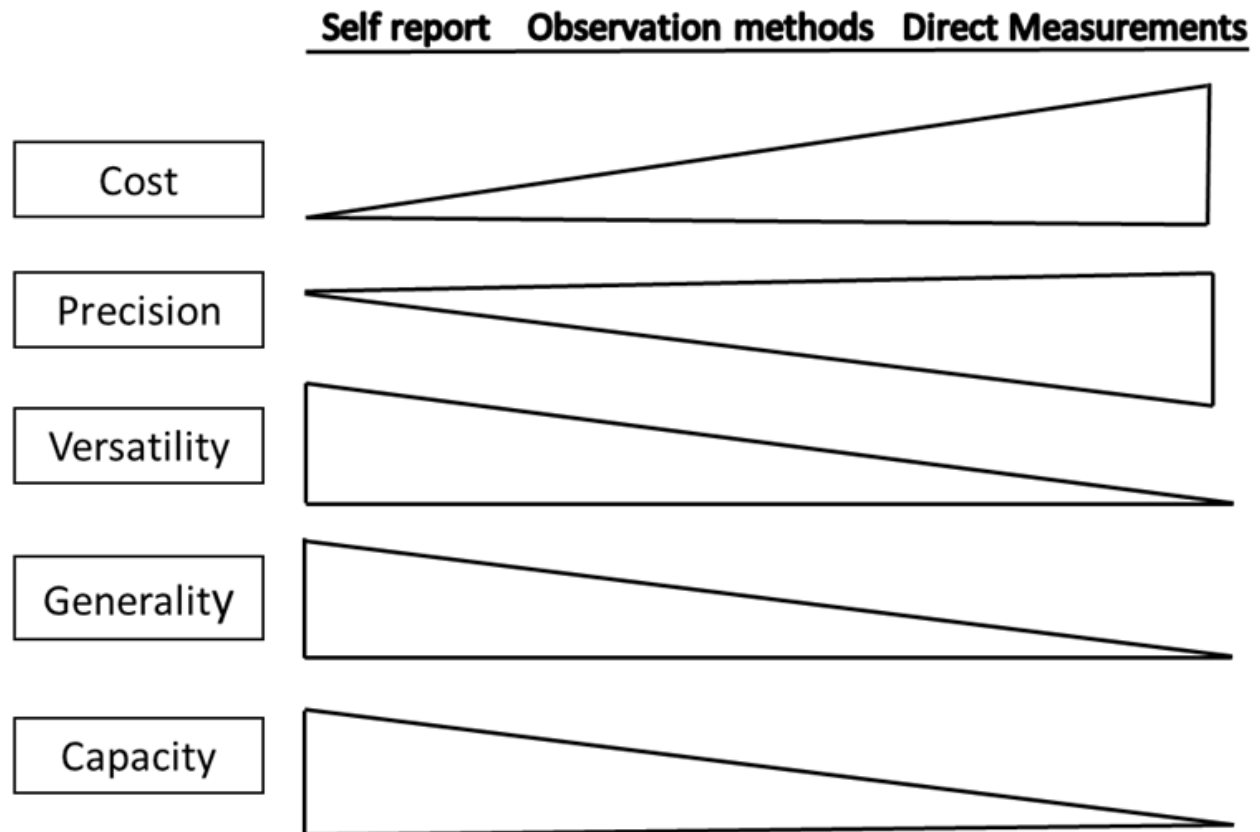


Figure 1.2. Differences between the three main strategies of data collection (adapted from Winkel and Mathiassen, 1994) (67)

1.6- Study objectives & rationale

Although a number of epidemiological studies and reviews have been conducted on LBD among the general working population, there is no systematic review synthesizing the evidence on posture as a risk factor for LBD specifically in the unique context of farming. Such a review is needed to summarize the current state of knowledge and the strength of the relationship between the posture and LBD in farming occupations.

In addition, lack of knowledge about exposure patterns has hampered prevention and intervention efforts for LBD. Static and repetitive awkward trunk postures are known to increase the risk of future LBD (52). The operational mechanical quantification of posture exposure and its cumulative effect are dependent on three mechanical domains: duration, frequency, and level/intensity (71). The

interaction between these domains can lead to changes in decreasing tissue load-tolerance over time (72). In order to develop appropriate recommendations for interventions, more information is needed on the level, frequency, and duration of posture exposure and what activities decrease or increase the posture exposure. However, the type of exposure measurement used in previous studies of LBD in farming do not provide consistent and valid information for prevention strategies or interventions.

Objectives: To address these gaps, this thesis offers two main parts: 1) a systematic review focusing on posture as a risk factor for LBD among farmers, and 2) a description of directly measured occupational postural exposure patterns among farmers.

1.6.1-Research questions and overview of manuscripts

In order to address some of the aforementioned gaps in the literature, this thesis focuses on the following research questions:

- 1- What is the current state of knowledge on trunk posture as a risk factor for low back disorders in farmers?
- 2- What are the patterns of trunk posture exposure among Saskatchewan farmers?

The research questions are addressed through two manuscripts:

- 1- Awkward working posture as a risk factor for low back disorders in farmers: A systematic review (manuscript 1)

2- Directly measured patterns of trunk posture exposure in Saskatchewan farmers (manuscript 2)

A comprehensive, systematic review of peer-reviewed literature will explore working trunk posture as a risk factor for LBD in farmers. A description of directly-measured exposure patterns will help to prioritize and identify the prevention opportunities for postural exposure. The results of these studies will provide a clear task description for farm workers and patterns of trunk posture exposure during farm tasks. In addition, the study will provide a base for future studies.

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Chapter-2: Manuscript-1

Awkward working posture as a risk factor for low back disorders in farmers: A systematic review

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Target Journal: Journal of Agromedicine

Muhammad Idrees Khan's contribution to this systematic review was the complete text screening, data extraction, data analysis, development of tables, figures, forest plots, and drafting the manuscript.

2.1- Abstract

Background: Low back disorders (LBD) are the most common musculoskeletal problem among farmers, with higher prevalence than other occupations. Although studies of the general population have shown an association between LBD and awkward working posture, the relationship may be different among farmers due to their unique work context and exposures.

Objectives: The objectives of this systematic review were to: 1) identify published research studies investigating posture as a risk factor for LBD in farmers/agricultural workers; 2) determine the strength of the relationship between postural exposure and LBD risk of bias assessment; and 3) make recommendations for future research.

Method: Comprehensive electronic searches of Medline, Web of Science, CINAHL, SCOPUS, PubMed, and EMBASE were carried out with combined conceptual groups of search terms for 'farming' and 'LBD.' After screening, data were extracted to summarize the study design, sample characteristics, exposure assessment methods, LBD risk factors, demographic information, data collection methods, farm commodities, job context, and sampling strategy. Data were synthesized to determine the weight of evidence for awkward working posture as a risk factor for LBD among farmers.

Results: The electronic search resulted in 1394 titles after excluding duplicates; 357 full-text articles were evaluated after screening and nine studies were included in this review. There were eight cross-sectional and one case-control study. However, there was diversity in exposure definition, exposure assessment, LBD definition, worker characteristics, and analytical approaches. Despite the diversity, the weight of evidence supported a relationship between awkward posture and LBD. Overall, the identified literature suggests an exposure-outcome relationship, although one study showed a protective effect.

Conclusion: All studies used self-report; there were no field-based studies including direct measurement of awkward posture. Well-designed epidemiological studies with quantitative physical workload assessments, consistent and valid LBD definitions, and longitudinal designs are recommended to clarify the relationship between awkward posture and LBD.

2.2- Introduction

Low back disorders (LBD) are a major economic and public health problem in high and low income countries (1–3). In the USA general population, it has been estimated that 76% to 85% people report experiencing LBD sometime in their life (4). LBD causes a significant level of disability, including restrictions on usual daily activities and work participation (5,6). LBD are responsible for 12% of all sick days(4). A systematic review conducted by Louw Q et al. (2007) reported that the global economic, societal, and public health effects of LBD are increasing (7). LBD also have tremendous costs; in 2006 the estimated cost of back pain in the United States exceeds \$100 to \$200 billion per year (6,8), Canada exceeded \$8.1 billion in 1998 (9), in 2014 medical expenditures related to LBD in Canada were between 6\$ and 12 billion dollars (10).

LBD are a major occupational health problem facing the agriculture workforce in particular (11). Musculoskeletal disorders are more prevalent in agriculture workers as compared to other occupational groups, and LBD are the most common musculoskeletal problem in agricultural workers (12). Agricultural workers have twice the risk of low back pain as compared to the general working population and are eight times more likely to change their work activities because of low back pain (13). Farm work can include many physically demanding work tasks, often involving a combination of high postural load, manual material handling, and high muscular force (14). When performing farm tasks such as lifting, machinery maintenance, driving, shoveling, and handling livestock, farmers may be particularly exposed to working in awkward body posture which can place a significant physical demand on the body, particularly the back (15). Although some systematic reviews have been conducted on risk factors for LBD in the general population, there is no systematic review focusing on awkward working posture as a risk factor for LBD specifically in farmers. Farmers have a unique occupational context that could modify this relationship. For example, farmers are exposed to long working hours, they start working at young age and work

beyond typical retirement age, and the seasonality, weather, and time pressure inherent in their work can increase the intensity of their exposure to awkward posture.

Developing and implementing appropriate preventive measures requires a deeper knowledge of awkward working posture as a risk factor for LBD in this workforce. Therefore, the objective of the present systematic review is to better understand the state of knowledge on the relationship between the working posture and LBD in farmers through a systematic review of primary research.

2.3- Methodology

2.3-1 Search strategy

Comprehensive electronic searches of OVID Medline, Web of Science, CINAHL, OVID EMBASE, OSH References, SCOPUS, PubMed, PEDro, and OT Seeker were carried out using two conceptual groups of search terms: 1) 'low back disorders' and 2) 'farmer' occupation (see appendix-1 for a full list of search terms). No limits on dates of publications were applied in the literature search; the search was performed in May 2017. The protocol for this systematic review is registered on PROSPERO and is available on the *Centre for Reviews and Dissemination* website (16). The search was limited to English-language articles and research studies on humans. Inclusion criteria included: 1) pertained to LBD defined broadly as "low back injuries, low back pain 12th rib to gluteal fold, hip/leg pain or symptoms, sciatica, and spine related arthritis"; 2) assessed awkward working posture; 3) used inferential statistics tests comparing postural exposure to LBD; and 4) involved a sample of adult farmers or agricultural workers. Letters to the editors, book reviews, review articles, and other non-primary articles were excluded.

2.3-2 Screening and selection process

At least two authors screened research articles independently at the title, abstract, and full-text stages. Articles on which researchers disagreed with inclusion were discussed in a team meeting to determine inclusion/elimination and help to refine the interpretation of inclusion/exclusion criteria. A complete schematic of the screening process is shown in figure 3.

2.3-3 Data Extraction

Data extraction included: demographic information; LBD case definition; exposure assessment and quantification; sampling time-frame; sample size; exposure level, duration, and frequency; and results from inferential tests to determine the strength of association. Data were extracted by two reviewers independently (MIK, OA) and reconciled through discussion. Disagreements were resolved via discussion with other research team members.

2.3-4 Risk of bias assessment

To determine the risk of bias of included studies, we applied selected items from a risk of bias (ROB) assessment tool developed for LBD prevalence research and previously published by Hoy et al. (5). Two data extractors (MIK, OA) performed ROB assessment independently and in parallel with data extraction, with disagreements resolved through group consensus. All items were binary (yes/no): for example “*Were data collected from the subjects (as oppose to a proxy)*” (yes/ no). Articles with an ‘*appropriate sampling frame*’ were articles that demonstrated that the study sample was a the true representation of the targeted population in terms of age, location, gender, employment context if the answer was yes it was considered low risk for bias. The ‘*random selection*’ criterion was met when a study demonstrated it adopted some form of random selection to avoid selection bias, or compared results to census data. The ‘*minimal non-response*’ criterion was considered to be met if a study demonstrated high participation or high response rate; 75% was considered the minimal response rate to meet this criterion. For the ‘*mode of data collection*’ criterion, studies that applied the same

method of data collection for all participants were considered to have met this criterion. An acceptable '*case definition*' clearly defined the criteria for LBD with a description of symptoms, time frame, and site of pain. An example of an acceptable LBD case definition would be the Standardized Nordic Questionnaire (17), which clearly defines the symptoms, site of pain, and includes a specific time frame. Although there are other aspects of study quality which are not addressed in the Hoy tool (for example, adjusting for potential confounders in multivariate analyses), they were not formally quantified and are instead discussed descriptively.

2.3-5 Descriptive presentation of results and sensitivity analysis

Forest plots were developed to summarize the included studies' findings. The forest plot of included studies with the following characteristics: reported an odds ratio; reported LBD 12-month prevalence; and used self-reported awkward posture for exposure assessment; there were no restrictions based on study design. In the case of two or more exposure categories, the odds ratio of the highest exposure category was included in the forest plot. The plot was developed using MedCalc statistical software (18).

Additional forest plots were developed to conduct a sensitivity analysis based on several characteristics, including the effect of including only studies which:

- 1) had acceptable LBD definitions (such as: low back injuries, low back pain 12th rib to gluteal fold, hip/leg pain or symptoms, sciatica, and spine related arthritis or LBD classified by duration as acute (pain lasting less than 6 weeks), sub-chronic (6 to 12 weeks), or chronic (more than 12 weeks) (19);
- 2) met all ROB criteria; 3) were conducted in high-income countries in North America, Europe, and the Antipodes; or 4) quantified exposure category cut-offs (such as number of hours or days exposed, or specific degrees of bending e.g. bending > 30°).

2.4- Results

The electronic search resulted in 1394 titles after excluding duplicates; 357 articles were evaluated in full text, and nine articles met the inclusion criteria. The results of the screening process are shown in Figure 3. A summary of the participant characteristics are included in Table 1; Table 2 summarizes the exposure assessment method, sampling strategies, and time frame, exposure categories, LBD definition, strength of association, and adjustment for confounders.

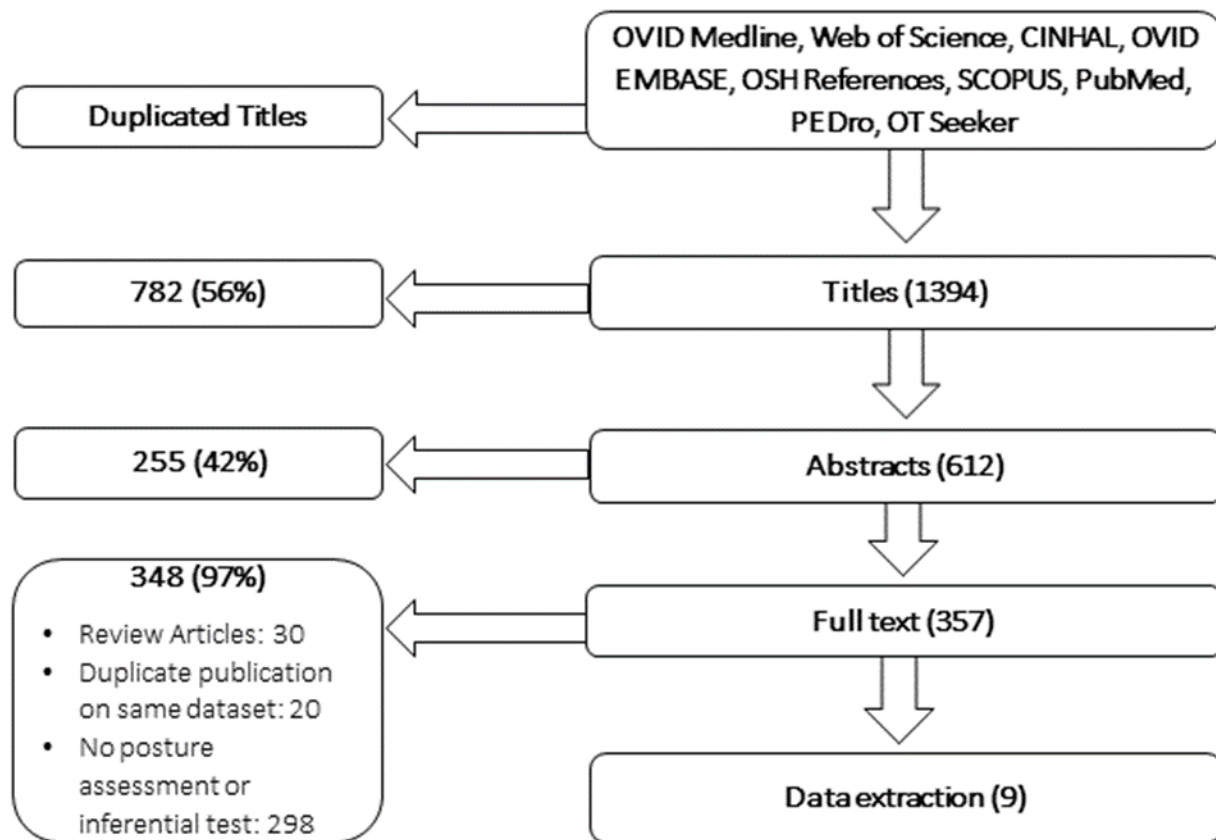


Figure 2.3. Results of search, screening, and extraction stages (May 2017)

2.4-1 Sample Characteristics

Two studies were conducted on men only (11,20), one on women only (21), and five studies included both men and women (22–26). One study did not report on sex or gender of the sample at all (27). Gender as a social construct was considered by only two articles (23,25), which interpreted

men's and women's different work posture according to the different job tasks in which men and women farm workers are typically involved.

Three studies reported the language, ethnicity, and education levels of the study participants (22,23,28); three studies reported only ethnicity (11,24,27), two studies only reported geographic location (25,26) and one study did not report any participant characteristics (20). Most studies were conducted in the high-income nations (11,20,23,24,29). In terms of the commodities produced on farms: four studies reported mixed commodities (i.e. both crops and animals) (11,20,26,27); three studies reported crop commodities (22,23,25); one study reported large-herd dairy farming (24); and one study did not report the type of commodity (28).

All nine studies used self-reported exposure assessment methods (11,20,22–28). Seven studies measured the exposure through in-person interview (11,23–28), one study assessed exposure through self-report via postal questionnaire (20), and two studies used self-administered questionnaire in the presence of researchers (22). None of the included studies in this review used direct exposure assessment methods.

Table 2.1. Characteristics of study participants and employment contexts of studies included in the systematic review

Author/Year	Region	N	Sex and gender	Ethnicity, education, language	Commodity	Employment Context
Naidoo, 2009	KwaZulu Nata	911	100% Female	Zulu (local language), educational level in years (Mean Education level for Irrigation and Dryland farmers 7.3 and 6.6 years respectively)	Not specified	Small-scale agriculture farming
Rosecrance et al., 2006	Kansas, USA	266	97.7% Male, Gender not considered	Not reported	Mixed: Soybeans, wheat, corn, milo, other plants, beef cattle, hogs, dairy cattle, sheep, goats, chickens, other animals	Seasonal farm workers
Hartman et al., 2005	Netherlands	198	Not reported	Dutch farmers	Mixed: Dairy farming, pig husbandry, poultry farming, arable farming, horticulture, bulb farming, fruit, plant	Self-employed
Holmberg et al., 2003	Sweden	657	100% Male, Gender not considered	Swedish farmers	Mixed: Dairy, crop growing, pig farming, cattle raising, others	Self-employed and employed farmers; Full time and part time
Meksawi et al., 2011	Southern Thailand	427	33% female and 67% male, Gender not considered	Thai rubber tappers, Educational level (Primary 70.2%, Secondary 16.2%, post-secondary 13.6%)	Crops: Rubber	Rubber plantation tappers
Xiao et al., 2013	Mendota, USA	843	44.6% female and 55% male, Gender not considered	Latino farm workers interviewed in Spanish, educational levels (No school 6.2%, primary 56.4%, > primary 37.5%)	Crops: Melon, tomatoes, nuts, grapes, cotton	Migrant and seasonal farm workers
Douphrate et al., 2016	USA	450	89.3% male and 10.6% female, Gender not considered	Five Western US states herd dairy farms, Hispanic workers	Dairy farming	Farm owners
Rodrigo et al., 2015	Southern Brazil	2469	59.3% male and 40.7% female, Gender considered	Education level (0-4=44%, 5-8=48.8%, ≥9=7.2%)	Tobacco	Seasonal workers
Kang et al., 2016	South Korea	15980	50.9% male and 49.1% female, Gender not considered	South Korean Farmers	Rice, vegetables, beans, sweet potatoes, potatoes	Self-employed

2.4-2 Strength of association between LBD and Posture

The overall sum of evidence was found to support an association between awkward working posture and LBD among farmers. The risk of LBD associated with posture for each study is summarized in Table 2. Six studies presented odds ratios (OR) (11,20,22,23,26,27) and three studies calculated prevalence ratio (PR)(24,25,28). Three studies found OR of the association between posture and LBD to be approximately equal to or greater than 2.0. In total, nine studies reported the strength of association between awkward working posture and LBD (11,20,22,24–26,29) seven studies showed significant associations (11,20,22,25–28), two studies showed non-significant associations (23,24), and out of seven, one study showed a protective effect of awkward posture (28). The strength of relationships reported in the included studies are presented in a forest plot in Figure 4.

2.4-3 Strength of association sensitivity analysis

The association between awkward posture and LBD was not affected by study characteristics. When considering only studies with low risk of bias, acceptable LBD case definition, quantified exposure categories, or high-income nations, there was no impact on the overall interpretation of evidence: evidence of an association between awkward posture and LBD persisted. (Appendix-4, Figure-1,2,3,4).

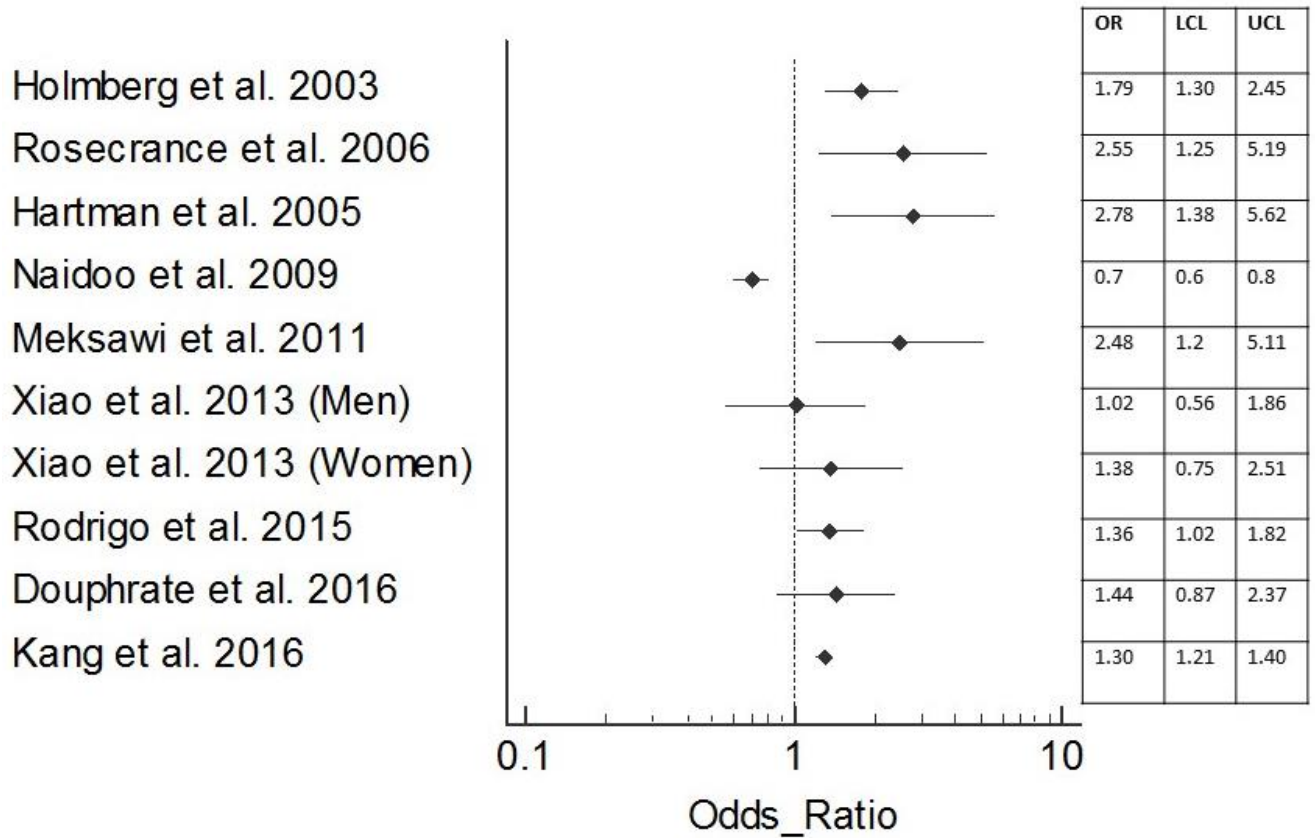


Figure 2.4. Forest plot of included studies: association between awkward working posture and LBD
Abbreviations: OR= odds ratio, LCL=lower 95 % confidence interval limit, UCL= upper 95% confidence interval limit

Table 2.2. Exposure assessment methods, outcome definitions, and association between awkward working posture and low back disorders in farmers. OR=Odds Ratio, PR= Prevalence Ratio, CI=Confidence Interval

Author/Year	Sampling strategy and time frame	Exposure assessment method	Exposure categories	Results of Inferential test/ adjustment
Hartman et al, 2005	Random sample, Farmers who had an insurance policy- sick leave claim in the period January 1998 up to December 2001]	Self-report via in-person interview	Bending or twisting >30 degrees 26/300h/year, (Ref= <26 h/yr) >300 h/year (Ref= <26 h/yr)	OR= 2.14, 95% CI= 1.04-4.42 OR=2.78, 95% CI= 1.38-5.62 * Adjusted: *Age, *BMI, Smoking, Work pace
Holmberg et al, 2003	Random sampling, 12 month period	Self-report via self-administered questionnaire and personal interview	Difficult working position Any (Ref=none, Assumed since not explicitly reported)	OR= 1.79, 95%CI= 1.30-2.45 *Adjusted: *Sex, *age, and place of residence
Meksawi et al, 2011	Systematic Random Sampling, October 2008 to February 2009, when the work was steady	Self-report via self-administered questionnaire and personal interview	Frequency of repetitive trunk twisting (Ref=mild bending) Moderate High Frequency of repetitive bending (Ref=mild bending) Moderate High Frequency of repetitive trunk extension (Ref=mild) Moderate High	OR= 1.43, 95% CI= 0.7-2.87 OR = 2.07, 95% CI= 1.07-3.99 OR= 1.42, 95% CI= 0.71-2.81 OR= 2.48, 95%CI= 1.2-5.11 OR= 0.73, 95%CI= 0.47-1.02 OR= 0.82, 95%CI= 0.43-1.21 OR=1.2, 95%CI= 1.00-1.35 *Adjusted: *Age, *Sex, *BMI, and underlying disease
Rosecrance et al, 2006	Quota sampling, the number of hours per day and the numbers of days per week	Self-reported exposure via postal questionnaire	“Working overhead” (Rating the problem on 0-10 scale, Ref = ≤5) ≥5	OR= 2.55, 95% CI= 1.25-5.19 *Adjusted:*Age, job factors "carrying, lifting, or moving materials, working when injured or hurt adjusted for other variables in the model.
Douphrate et al, 2016	Work related (i.e., time working in the parlor, work shift, having other nondairy job) Convenience Sample	Self-reported via self-administered questionnaire	“Bending/twisting back in an awkward way” (Ref=any vs none)	PR= 1.44, 95%CI= 0.87–2.37 * Adjusted: *gender, height, arm length, shift, having been kicked, and hours worked per day

Table 2.2 (Cont'd) Exposure assessment methods outcome definitions and association between awkward working posture and low back disorders in farmers. OR=Odds Ratio, PR= Prevalence Ratio, CI=Confidence Interval

Author/Year	Sampling strategy and time frame	Exposure assessment method	Exposure categories	Results of Inferential test/ adjustment
Naidoo et al, 2009	Convenience sampling, June to August 2006	Self-reported via in-person interview	<p>“Working in awkward position”</p> <p>“Frequent squatting and kneeling” (workers were asked to rate the frequency with which they performed the tasks including awkward posture) (Ref = low exposure vs high exposure)</p>	<p>PR= 0.7, 95%CI= 0.6-0.8</p> <p>PR= 1.7, 95%CI= 1.4-2.1</p>
Xiao et al, 2013	Stratified random sampling January 2006 to April 2007	Self-report via in-person interview	<p>“Stooped over or bent down”</p> <p>REF=<1 (women) 1<30 h/week ≥30 hours/week</p> <p>(men) 1<30 h/week ≥30 h/week</p>	<p>OR= 0.74, 95%CI= 0.34-1.63</p> <p>OR= 1.38, 95%CI= 0.75-2.51</p> <p>OR= 0.77, 95%CI=0.44-1.36</p> <p>OR= 1.02, 95%CI=0.56-1.86</p> <p>*Adjusted: *Age, years working in agriculture, and smoking</p>
Rodrigo et al, 2015	Not Reported	Self-reported questionnaire	” Working in awkward postures” (Ref = none)	PR= 1.36, 95%CI= 1.02-1.82 *Adjusted: *age, *gender, education, occupational history, green tobacco sickness, pesticide poisoning, and minor psychiatric disorders
Kang et al, 2016	Not Reported	Self-reported via personal interview	<p>“Bending or twisting upper body” (Ref= <4hr/day) >4hr/day</p> <p>“Kneeling or Squatting” >4hr/day</p>	<p>OR= 1.30, 95%CI= 1.21–1.40</p> <p>OR= 1.15, 95%CI= 1.07-1.23</p> <p>*Adjusted: *age and *sex using Logistic regression model</p>

2.4-2 Risk of Bias Assessment

The risk of bias assessment is summarized in Table 3. Out of nine included studies, six studies met all the Hoy et al (5) risk of bias assessment criteria (20,23–25,27,28) and three studies did not (11,22,26). Five studies had acceptable LBD definitions (20,23–25,28) while three studies had unacceptable definitions. Examples of unacceptable definitions included using administrative data to determine sick leave due to back pain (27) and using self-administered questionnaires collecting information about ache, pain, or discomfort experienced in the lower back area without a reported time frame (11, 30).

Table 2.3. Risk of Bias Assessment for studies investigating awkward posture and low back disorders among farmers (n=9)

Author/Year	Q-1	Q-2	Q-3	Q-4	Q-5	Q-6	Q-7	Q-8	Q-9	Q-10
Naidoo et al., 2009	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Rosecrance et al., 2006	N	Y	N	Y	Y	Y	Y	Y	Y	Y
Hartman et al., 2005	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Holmberg et al., 2003	Y	Y	Y	Y	Y	N	Y	Y	N	Y
Meksawi et al., 2011	Y	Y	Y	Y	N	Not specified	Y	Y	Y	Y
Xiao et al., 2013	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Douphrate et al., 2016	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Rodrigo et al., 2015	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Kang et al., 2016	Y	Y	Y	Y	N	N	N	Y	Y	Y

Q 1 Was the sampling frame a true or close representation of the target population?

Q 2 Was some form of random selection used to select the sample, OR, was a census undertaken?

Q 3 Was the likelihood of nonresponse bias minimal?

Q 4 Were data collected directly from the subjects (as opposed to a proxy)?

Q 5 Was an acceptable case definition used in the study?

Q 6 How was the quality of LBD definition captured?

Q 7 Was the study instrument that measured the parameter of interest (e.g. prevalence of LBD) shown to have reliability and validity (if necessary)?

Q 8 Was the same mode of data collection used for all subjects?

Q 9 Was the length of the shortest prevalence period for the parameter of interest appropriate?

Q10 Were the numerator (s) and denominator (s) for the parameter of interest appropriate?

2.5- Discussion

2.5-1 Summary of evidence

This systematic review was conducted to examine whether awkward working posture is a risk factor for LBD among farmers and agricultural workers. Due to heterogeneity in the included studies for posture exposure, level, frequency, and duration, LBD definitions, and different adjustments for risk estimates, a meta-analysis was not possible. Despite the diversity of studies included in this review, a qualitative assessment of the weight of evidence supports a relationship between awkward working posture and risk for LBD among farmers. Six of the nine included studies (20,23–25,27,28) met all the risk of bias criteria set out by Hoy et al.(5).

2.5-2 Statistical approaches

The included studies in the present review used varied statistical approaches. Out of nine studies, six calculated odds ratios (ORs) to quantify the relationship between posture and LBDs (11,20,22,23,26,27) while three studies calculated prevalence ratios (PRs)(24,25,28). Both the ORs and PRs are appropriate to answer the research question because both are measures of association that quantify the relationship between awkward posture and LBD. Thompson et al. suggest that the PR is a consistent, conventional, and interpretable effect measure appropriate for the analysis of survey data/cross-sectional studies (31). Naidoo et al authored the only study that showed a protective effect of awkward posture, in northern KwaZulu-Natal, South Africa farm workers (PR 0.7, 95% CI 0.6-0.8) (28). Even so, the authors suggested that there actually is an association between working in awkward posture and LBD, and acknowledge their results are contrary from previous published studies. Naidoo et al. explained two potential reasons for not finding association between farming activities and LBD: 1) “those working in awkward postures were likely to take frequent breaks and thus did not report the presence of chronic pain”; and 2) the nature of the cross

sectional study design (28). In a cross-sectional study, those performing the hardest work may be those with the least symptoms and therefore the greatest capacity for that work, consistent with a healthy worker effect. In addition, the exposure question asked by Naidoo et al for awkward working posture was not specific and did not explicitly define the duration or level of awkward posture; it could be that workers could not interpret the question correctly and this resulted in exposure misclassification. Holmberg et al also used a very non-specific question to study the association between awkward posture and LBD, but did find an association between awkward working posture and LBD in Swedish farm workers. There may be cultural, language, and social differences in interpreting loosely-defined questions.

Douphrate et al studied the relationship between awkward posture and LBD in farmers working in large-herd dairy farms in the USA. The authors reported a non-significant association (PR 1.44, 95% CI (0.87-2.37) when adjusting for possible confounders such as gender, height, arm length, and working hours (24). These findings on hired dairy workers (24) were not consistent with results from farm owner/ operators (32,33), perhaps reflecting the impact of occupational role on the farm. The part-time hired workers included in the Douphrate study likely performed milking tasks for fewer hours than full-time workers or owner operators (24). Furthermore, the study design was cross-sectional, each milking parlor worker was surveyed only one time, which prevents determining a causal relationship due to lack of temporality (24) Rodrigo et al. also reported a significant positive association between awkward posture and LBD (PR 1.36, 95%CI 1.02-1.82) and adjusted for confounders such as green tobacco sickness and previous occupational exposure (25). Rodrigo et al. reported that the main limitation of the study was not adjusting for BMI as a confounder, which is a known risk factor for LBD (25).

The point estimates of the ORs varied between 0.7 and 3.0. Confidence intervals show the precision of the point estimates, specify the range of plausible values of the ORs, and define statistical significance of association between working in awkward posture and LBD (34). Wide confidence intervals may be related to small sample size, variability within the sample, or other methodological errors. (34). In the present review, there is a range of confidence interval sizes likely related to a range in sample sizes (170 to 15000) and other methodological issues such as data collection methods. The forest plot in Figure 4 showed that six studies found a positive significant association between posture and LBD in farmers(11,20,22,25–27), two studies reported non-significant associations (23,24).

LBD are multi-factorial and are affected by multiple risk factors across multiple dimensions (35). The included studies in this review accounted for several potential confounding factors such as sex/gender, age, body mass index (BMI), years working in farming, smoking, physical exertion, education, height, and weight (11,20,22–28). However, the studies included in the present review did not consider general or work-related psychosocial factors such as stress, depression, and job satisfaction, which can confound the association between awkward working posture and LBD. Linton et al reported that psychosocial factors are potential risk factors for future LBD (35). A broader range of psychosocial factors should be considered in future studies of farm workers, since previous research demonstrated their importance in other occupational groups (36). Previous research in different occupational settings propose that biopsychosocial factors may interact or develop together to increase the risk of LBD (35). Further research regarding biopsychosocial factors and mechanisms will lead to greater understandings in the areas of etiology, assessment, treatment, and prevention strategies for LBD (37). Future research should also consider larger

sample sizes to ensure fully powered studies and statistical approaches such as PR or OR with adjustment for known confounders for LBD.

2.5-3 Study design and risk of bias

In the present review, eight studies adopted a cross-sectional study design (11,20,22–26,28) and one study used a case-control study design (29). Although a cross-sectional study is relatively easier to conduct, less time consuming, less expensive, and requires no follow-up, it cannot measure the temporality of cause and effect relationships. The greatest utility of the cross-sectional study is to describe the magnitude and distribution (i.e. prevalence) of a health condition. The association between LBD and awkward working posture determined with cross-sectional studies could be potentially biased due to the limitations of the cross-sectional study design (11,20,22–26,28). One case-control study included in the present review found an association between LBD and awkward working posture (27), but the evidence on causality from case-control studies is considered low as compared to a cohort or longitudinal studies(38). There is also a threat to validity in non-cohort designs due to selection bias and recall bias, because at the time of participants' recruitment both the outcome and exposure have already happened (38). Although the Hoy et al risk of bias tool a relatively well established and specific for back pain, it does not cover all potential aspects of bias. For example, confounding for relevant factors, temporality, and recall bias were not considered in this tool.

Some of the studies included in this review used unrepresentative sampling frames, and did not meet the Hoy et al. criteria for LBD definition. Due to inadequate sampling, there is potential for underrepresentation of several groups, for example those who are retired or not working because of LBD-related disability (i.e. healthy worker effect). Self-reported health outcomes may be under-reported due to recall issues, as participants may have inaccurate recall of health outcomes. This

review corroborates that researchers should adopt prospective cohort study designs, which would be more appropriate to elucidate cause and effect relationships.

2.5-4 Case definition

In the present review, various types of LBD definitions were included to capture the larger volume of evidence. Thus, there is diversity in LBD definition across the included studies. This diversity is typical in LBD research; there is no standardized definition for LBD which is a major problem for researchers (39). A sensitivity analyses was performed considering only 'high quality LBD definitions'. The results were still the same and were not sensitive to LBD definition (Appendix 3 figure 1). Clermont et al suggested that an acceptable LBD definition should include the site of the LBD, observed symptoms, measure of severity (level), and time frame of the measure with frequency and duration of symptoms (30).

LBD definitions in this systematic review spanned a few broad categories: previously published "Standardized Nordic Questionnaire" (20,24,28), self-report through the unspecified self-administered questionnaire (11,23,25,26), and cases defining LBD through sick leave (27), and one study did not specify the LBD definition (22). There were also differences in the prevalence period for LBD. Six studies defined LBD as pain in the lower back over the past 12 months (11,20,24,26–28), two studies defined LBD similarly but over the past three months (22,25), and one defined LBD as pain lasting six weeks or longer (23). Despite substantial published literature regarding LBD prevalence and incidence in general populations, there is a lack of consistency in the definition of LBD (40). Furthermore, LBD are comprised of many different pathologies and underlying conditions with the majority of cases being classified as non-specific low back pain (41,42). It is widely accepted that LBD are multifactorial in nature; the patho-anatomical, physical, psychological, social, and neurophysiological factors are different for each person (39). This general classification

leads to problems in research methodology, as researchers have no standardized LBD definition. The present review conducted the sensitivity analysis based on LBD definition (see figure-1 in appendix-3). However, even when only acceptable case definitions were considered, the overall weight of evidence remained in favour of an association between awkward working posture and LBD.

2.5-5 Exposure assessment methodology

Exposure assessment methodologies are typically split into three main categories: observation, direct measurement, and self-report (43,44). Observation methods can include observations at workplace such as with video based observational techniques; check list, and a tool such as the strain index. Observational methods have high cost, less generalizability, low capacity, and less versatility as compared to self-report methods and also require trained staff (45). Direct exposure measurement (such as inclinometer, accelerometer, and inertial sensors) collects more precise and objective data as compared to self-reported data (46), and can also remove the issues of response and recall bias. There are also challenges with direct exposure measurement; they are expensive as compared to self-report and observation methods due to the high cost of equipment, technician monitoring, and require a more processing time (45). Although direct exposure assessment provides more accurate and reliable data, this method can only provide information regarding the recorded working period and typically small sample sizes (46). In the present study, neither observation nor direct measurement was employed.

Self-report methods can be used to study a large number of participants at a very low cost and require less time as compared to direct measurement methods. However, previous methodological studies showed low validity and reliability for self-reported methods (46). In the studies included in this review, self-reported posture exposure was assessed using in-person interviews and postal

questionnaires. Information collected with self-report methods may lead to systematic bias and lack of precision (47). Other potential problems with questionnaires are low response rates, the participants may not respond to individual questions, recall bias, and social desirability bias (47). In-person interviews may provide more in-depth data collection and comprehensive understanding of work exposure as compared to questionnaires (48). The researcher can ask for explanations of responses for more clarification of work exposure duration, level, and frequency. However, information collected with in-person interviews may also lead to bias as the responses may not provide accurate work exposure information (47). The one main problem with self-reported methods is that the worker's perception of exposure may be imprecise (47). For example, a worker with severe low back pain may report higher duration and frequency of tasks or other working exposures as compared to the workers in the same occupational group who do not have low back pain (49). Further, challenges with self-report may arise due to different level of workers literacy, and understanding or interpretation of question (48). The included studies in the review used solely self-reported exposure assessment.

Winkle and Mathissen quantified the exposure in three dimensions: level (concentration or amplitude), duration (time), and frequency (repetitiveness)(46). Winkle and Mathissen further explain that the level of exposure is the magnitude of the mechanical forces, repetitiveness are the frequencies of shifts among these force levels, and duration is the time of extension of the exposure to these mechanical forces (46). In the present review two studies measured exposure with duration (11,20), two studies measured level and frequency (25,28), one study measured all three dimensions (duration, level, and frequency) (29), one study measured duration and frequency(22), and three studies reported exposure assessment in terms of frequency only (23,26,50). Imprecise or incomplete self-reported exposure assessments provide little guidance in setting exposure limits or

targeting risky exposures. The results of the review suggests that investigation of posture as a risk factor for LBD in farmers should incorporate direct measurement methods that can assess the level (e.g. the degree of bending) , duration (e.g. the length of time to bending in particular degrees of bending or posture) , and frequency (e.g. number of times bend in particular degrees of bending) of awkward posture in a more precise way.

Even though the included studies were conducted in very diverse in settings, the weight of evidence supports the notion of trunk posture as a risk factor for LBD in farm workers. Researchers recommended that there is a need to improve the quantitative measurement of postural exposure at the workplace (21). Ideally, studies investigating the association of posture with LBD among farm workers will use direct measurement methods which will provide more precise measurement of exposure (level, frequency, and duration). In order to address the technical and logistical challenges with direct measurement methods, pilot studies within farm worker populations should be done to demonstrate the feasibility of direct measurement in these more geographically remote and spread-out rural environments and potentially long working days.

2.5-6 Study context and participant characteristics

This review found substantial diversity among studies in terms of geographical region, farm commodity, employment status, participant age, ethnicity, sex, and gender. In terms of geography, the nine studies were conducted across five continents; type of commodity likely had an impact on nature of work and type of machinery used. Commodities are also diverse based on farming region. Agriculture practices are diversified due to economic and regional differences (51), and the majority of studies included in this review were conducted in high-income countries such as the USA, Sweden, and Netherlands. These countries practice farming on a large scale with high-tech machinery, while low-income countries like India, Brazil, and Thailand may be more reliant on

manual work and traditional farming practices (52), for example working in awkward working postures such as prolonged stooping in rice farmers (53,54). Das et al. concluded that the rice cultivators are more exposed to heavy manual work in awkward working posture for a prolonged period, which leads to LBD (54). This is contrasted with North American grain production which is heavily mechanized. The focus in the literature on high income nations means less is known about the epidemiology of LBD in developing nations (6,55). However, when only high-income nations were considered, the overall weight of evidence still supported an association between awkward working posture and LBD (see figure 4 in appendix 3).

Personal factors such as age, sex, (56) and ethnicity (57) are considered important risk factors in the development of LBD. Age and sex are important confounders when examining the association between posture and LBD (11,22,23,26). When considering the one included study which did not report sex of the sample (27), it seems unlikely that the researchers controlled for it in the analysis. The included studies had a higher number of men in comparison to women. In terms of gender, men and women may have different working postures according to different job tasks on farms (23); in terms of sex, their risk factors for LBD can be impacted by physiological and anatomical differences (55). Other risk factors for LBD can also be affected by social roles prescribed by a person's gender (55), but gender as a social construct is discussed by only two articles in this review (23,25). There is a substantial gap and underrepresentation of women in farming research, even though women comprise much of the farming workforce (58); the ILO reports that at least half of the global farming workforce consists of women (13). Due to an increasing proportion of women in the farming workforce, researchers should also focus on women's roles in farming, particularly in low-income countries. Overall, the included studies in the review focused on high-income nations which are not representative of the global agricultural workforce. To improve this under-

representation, future studies should also focus on women in farming occupations in both high and lower income nations.

Four of the nine studies reported educational level, language, and ethnicity of participants (22,23,25,28), four studies reported ethnicity only (11,24,26,27), and one study did not report any of characteristics (20). Although ethnicity is a strong determinant of health (52), there is no clear association reported between LBD and ethnicity. According to previous research reported by the Food and Agriculture Organization (FAO) of the United Nations , there is a relationship between social status and education with the occurrence of back pain in agriculture (52), suggesting that low educational levels may act as a surrogate measure for social class and increased biomechanical exposures in physically demanding occupations (55).

The diversity of employment contexts may impact the association between working in awkward posture and LBD. In terms of employment status, three studies included seasonal and migrant farm workers (20,23,25); four studies included self-employed, owner, and employed (part time and full time) farm workers (11,24,26,27), and two studies included small-scale farming (rice farmers, small-scale agriculture, rubber plantation, tapping) (22,28). In high-income nations, seasonal and migrant farm workers may work on farms and this group may be harder to follow-up, particularly in cohort studies. Furthermore, the exposure of part-time farm workers in both high- and low-income nations may be more difficult to study because of differences in demographics, economic, social and employment contexts in comparison to owner/ operators or full time farm workers.

2.5-7 Risk of bias assessment

The Hoy et al. (5) tool was used to examine each included study to assess risk of bias. The “direct data collection” criterion was rated ‘yes’ across all studies, meaning that the data was directly collected from the participants and no proxy was used to collect the data. Criteria for

“representation,” “non-response bias” and “acceptable LBD case definition” were rated “no” on only one study each. The majority of the included studies, except one (24), reported using a random sampling method. The unique strength of random sampling is that, if successfully achieved, it will improve the validity of generalizability and prevents selection bias. In the present review, there is diversity in the time frames for LBD prevalence ranging from 3 to 12 months. Researchers should consider using standardized time frames for prevalence data collection (such as 12 months prevalence as in the Standardized Nordic Questionnaire) (17). It should be noted that the Hoy et al tool was designed for LBD prevalence studies, so it does not evaluate the sources of bias related to: exposure assessment, potential confounding, and temporality of the relationship. Therefore, meeting all of the Hoy tool criteria does not necessarily indicate low risk of bias for an exposure response study. Nonetheless, the present review conducted a sensitivity analysis based on findings from the risk of bias assessment (see figure-2 in appendix-3). When considering only the six out of nine studies that met all the risk of bias criteria, the weight of evidence still showed an association between awkward working posture and LBD.

2.6- Strengths and Limitations

This review has several strengths. According to our knowledge, the present review is the first to study the strength of association between awkward working posture and LBD within the context of agricultural work. Dual independent article screening and data extraction were performed as described in the registered protocol (16). The review also provided details about methods of exposure assessment and recommendations for future research. In terms of risk of bias, a standardized tool was used (5).

This review also has some limitations. The present review included English language articles only; excluding non-English articles may have limited access to international literature. There is also the possibility that some research articles published in smaller or low-impact journals that may not be

included in these academic research databases. The present review found substantial diversity among the nine studies, which make comparison by meta-analysis and generalizability to all farmers challenging.

2.7- Conclusion

Due to the diversity in LBD definition, inferential test, type of commodity, and study design, we could not perform a meta-analysis. However, despite the diversity of study settings and employment contexts, this review found that the weight of evidence suggests an association between awkward working posture and LBD in farmers; the proposed mechanism also has high biological plausibility (59). Larger samples of more homogeneous groups of farmers are needed to explore the relationship specific to posture and LBD. A better understanding of the association between awkward working posture and LBD will help to design interventions to reduce the prevalence and burden of LBD among farming populations.

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Chapter-3: Manuscript-2

Awkward working posture exposure patterns in Saskatchewan farmers

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Muhammad Idrees Khan's contribution to this manuscript was, piloting the study before going to farms for data collection, recruitment of participants, collecting trunk posture exposure data through I2M motion sensor on farms, data management, analysis, and dissemination through manuscript writing.

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Abstract

Background and Objectives

Low back disorder (LBD) is the most common musculoskeletal disorder among farmers, with a lifetime prevalence of up to 75%. LBD is associated with loss of productivity, quality of life, and farm revenue. Awkward body postures, such as working overhead, kneeling, squatting, repetitive bending and reaching can place a significant physical demand on a worker's body, particularly the back. High exposure to these awkward working postures along with the aging of farm workers leads to a substantial risk for LBD. Due to the cost and feasibility of on-farm measurement, not much is known about awkward posture exposure patterns in farmers. The objective of this study was to determine the patterns of working trunk posture among Saskatchewan farmers.

Methods

Forty-nine adult farm workers from 22 farms participated in this study. Individual characteristics and farm characteristics were documented via questionnaire. Trunk posture and velocity were measured with an I2M inertial sensor placed on the chest. Participants completed up to three repeated electronic posture assessments during up to three regular work days throughout the growing season for a total of 91 electronic posture measurements. Forward and lateral trunk bending patterns were expressed in three domains; duration, level, and frequency.

Results

Working tasks were categorized into driving, manual, and mixed. Driving was the most commonly measured task (52%), and mixed tasks were least often measured (12%). The 90th percentile trunk flexion-extension angle was significantly higher for manual as compared to driving tasks, and the 90th percentile flexion-extension velocities were also significantly higher for manual than driving tasks. Participants spent 38% of their working time in trunk forward flexion $\geq 20^\circ$, which according to previous epidemiological studies may increase their risk for LBD.

Conclusion

The high-quality, directly-measured trunk posture exposure patterns in this study can lead to better prevention strategies for LBD prevention in the understudied rural population of Saskatchewan farm workers.

3.1- Introduction

Low back disorders (LBD) are a common work-related musculoskeletal disorder (MSD) with an estimated life time prevalence ranging from 11% to 84% in the general adult population (1).

Globally, 80% to 90% of the general adult population will likely experience LBD in their life time (1). LBD cause significant morbidity, disability, and economic loss among workers (2,3). LBD are the most prevalent MSD in farmers with a life time prevalence of 75% (4). Farm work includes many physically heavy work tasks such as lifting, carrying heavy loads, repetitive jobs for long periods of time, long exposure to whole body vibration from vehicles (e.g. tractors), high work pressure, risk of fall and trips, unpredictable action of livestock, and working with the trunk in awkward positions (2,3).

Occupational posture refers to the positions that a worker assumes to perform a task or job. Neutral body posture (i.e., anatomical position) represents a position with minimal strain on muscles and joints (5). Any posture in which the body moves away from neutral posture is considered 'awkward' posture (5). Occupational exposure to static and/or repetitive awkward postures has been shown to be associated with LBD (6,7). A review conducted by Burdorf et al. found nine articles out of ten reported a positive association between LBD and work-related awkward posture (8). A study conducted by Liira et al. reported a relatively strong association between awkward posture and LBD (OR 2.33, 95%CI 1.72-3.15) among occupational workers exposed to physical work (9).

Awkward postures require muscles to work harder and can stress passive structures such as ligaments and discs (5,10). The cumulative effect of awkward posture is dependent on the level (degree of bending), duration (time), and frequency (repetitiveness). The interaction between these three domains leads to a cumulative decrease of tissue load-tolerance over time (5,11). The effect of awkward posture can be severe if also applying force while in an awkward position (such as lifting

while stooped over or a strong grip in a bent position), while maintaining one position for a long period (sustained/static duration), or repeatedly moving in an awkward posture (5). Posture exposure patterns can be complex, but high-quality direct exposure assessments that reflect this complexity are relatively rare.(12). An in-depth understanding of exposure is required before effective prevention strategies can be developed.

There are several challenges to directly measuring occupational posture among farmers. It can be time-consuming, expensive, and the farming population is also typically geographically dispersed. Furthermore, most farmers are self-employed and rarely have unions or corporate employers that can facilitate research recruitment. With a few notable exceptions (13), very few field-based research studies have used direct measurement approaches on postural biomechanical exposure metrics in agriculture (14); detailed assessment of exposure patterns are necessary to truly understand the development of LBD from biomechanical exposures (15). A systematic review by Khan et al. (in preparation) found that studies investigating the association between awkward posture and LBD among agricultural worker have not used directly measured posture or assess exposure patterns among farmers (16). Further information is needed on directly measured exposure patterns among farmers, so that high-risk sub-groups and tasks can be identified to target prevention efforts. To this end, the objectives of the present study were to 1) directly measure working posture of farmers throughout a growing season; 2) describe exposure patterns among Saskatchewan farmers in terms of level, frequency, and duration; 3) compare working posture among different farm tasks.

3.2 – Methodology

3.2-1 Study participants

This one-year field-based study was conducted in the Canadian province of Saskatchewan and nested within a larger study called the Saskatchewan Farm Injury Cohort Study (SFIC) (17). The SFIC evaluated the potential causes of injury to Saskatchewan farmer among a cohort of 2,390 farms and 5,492 farm workers followed over a two-year period (17). SFIC participants were asked as part of the baseline survey if they willing to be contacted regarding a research visit to their farm. Farms that responded with their contact information and resided within 400km of Saskatoon were considered eligible for on-farm measurements.

Potential participants for on-farm measurements were informed about the study purpose and methods through an introductory letter and then invited to participate via follow-up phone call. For the present study, eligible participants performed farm tasks for at least 12 weeks of the year. Once a farm was recruited, 1-4 additional farm workers were recruited to participate. Both farm owners and farm employees were eligible to participate in the study. Up to three visits to each farm were scheduled throughout a one-year period to account for seasonal variability in work tasks and exposures: spring (April-May); summer (June-July); and fall (August-November). All the farm visits were completed between March and November 2015. This study was approved by the Research Ethics Board of the University of Saskatchewan, and informed consent was obtained from all participants.

3.2-2 Electronic posture assessment

Trunk posture was measured using wearable, portable, data-logging, battery-powered Inertial Measurement Unit sensors (I2M motion sensors Series SXT IMUs, Nexgen Ergonomics, Inc., Pointe Claire, Quebec), consisting of Triaxle Accelerometer ($\pm 6g$), Triaxle Gyroscope (± 2000

deg/s), collected at a rate of 64 HZ sample per second. The I2M posture sensor was strapped on the participant's chest in an elastic harness over the sternum at the level of the 3rd rib. Neutral standing 'zero' angles were recorded during a series of relaxed upright calibration (reference) postures before starting measurements. A second upright calibration posture was performed at the end of the workday.

During measurement visits, farmers performed their regular farm tasks without direction from the research team. Farmers were considered to be performing 'working postures' once they started their work tasks. Since farms were located a considerable distance from the university, it was not possible to capture a full work day, which on farms can exceed 12 hours. The typical work measurement was 4 to 5 hours per day. Each participant completed a self-administered questionnaire which included demographic characteristics including: age, sex, BMI, weight, and farm characteristics. At the conclusion of each measurement day, a summary of work task hours was recorded by the researchers (e.g., 3 hours on tractor, 4 hours machinery maintenance, 2 hours shoveling out grain bins.) These activities were subsequently categorized as 'driving' or 'manual' tasks. If a farm worker spent more than 80% of the working day driving (combine, tractor, sprayer, grain truck, etc.), the predominant task during that day was considered 'driving.' If the farm worker spent more than 80% of the work time on manual activities (such as farm machinery maintenance, moving material such as hay bales or grain shoveling), it was considered a 'manual' task day. 'Mixed' task work days were those in which the farmer spent less than 80% of the working time in either driving or manual tasks.

3.2-3 Data processing

A custom program developed in MATLAB V.R 2015a (Mathwork Inc, Natick, MA USA) was used to summarize the posture measurements for each day. Forward flexion was assigned positive values

and extension negative values. Lateral flexion to the left side was assigned negative values and the right side positive values.

Posture measurements were collected by the inertial sensor in three dimensions, X, Y, and Z, relative to gravity. X-axis is superior/inferior and was oriented with gravity, X was (-) when the sensor was between 0° and 90° of forward/backward inclination, X and Z axis was (+) when sensor was beyond 90° of forward inclination; Y axis was oriented with lateral flexion, right inclination was considered positive (+) and left inclination was considered negative (-); Z axis was considered anterior-posterior, forward bending was considered positive (+) and backward was considered negative (-). Acceleration was measured with an accelerometer, and angular velocity measured with a gyroscope. All the data streams were smoothed with a 4th order dual low-pass Butterworth filter at 2.5 Hz. Trunk inclination angles were estimated from the triaxle accelerometers, the flexion/extension angles were calculated as the arctangent $\tan^{-1} (A_z/A_x)$, and inclination angles for lateral flexion were calculated as $\tan^{-1} (A_y/A_x)$ (8,18). To account for mounting offset, the average ‘standing upright’ value of the calibration postures was subtracted from the working postures.

Daily postures were summarized in terms of a series of metrics previously reported by Kazmierczak et al. (19). Posture level was summarized in terms of 10th percentile as an estimate of the ‘static’ or minimal value (°), 50th percentile as a measure of central tendency (°), and 90th percentile as an estimate of peak angle (°) (see tables 5 and 6 for a full listing of metrics). Posture velocity was calculated as absolute value of angular displacement over time, then also summarized in terms of 10th, 50th, and 90th percentiles (°/s).

The following thresholds were set for ‘neutral’ and ‘extreme’ trunk posture according to the ISO standard on working postures (20): percent time in neutral posture < 20° (forward flexion-extension and lateral flexion); percent time in ‘extreme’ posture > 60° (forward flexion-extension); frequency

of periods greater than 3 seconds in a 'neutral' posture (forward flexion-extension 0-20° and lateral flexion < +20°); percent time at low velocities < 5°/s, percent time at high velocities > 90°/s (forward flexion-extension and lateral flexion); and percent time at rest (velocity < 5°/s and natural posture as defined above).

To ensure data quality, all posture data files were visually inspected for excess noise or signal drop, a discontinuity in data logging, or corrupted files. Distribution of summary metrics was also visually inspected to check for outliers; any outliers were double-checked with corresponding task videos (collected for a separate analysis), questionnaire data, and task records collected during farm visits. If the task video, questionnaire data, and task records did not heuristically support the metric's values, the variable was discarded for that participant/day.

3.2-4 Statistical Analysis

Descriptive statistics including frequencies, mean, median, minimum, and maximum values were calculated for socio-demographic and work characteristics.

Distribution of exposure metrics was assessed for normality using visual inspection of histograms, Kolmogorov-Smirnov tests, and assessing skewness; skewness values between -1 and +1 were considered normal. The deviation from skewness range was considered as a non-normal variable.

Non-normally distributed metrics were summarized with medians and interquartile range rather than means and standard deviations. Due to the hierarchical structure of repeated measures, non-normal distributions, and unbalanced nature of the data set, Generalized Estimation Equations (GEE) were used to investigate differences between task types (driving, manual, and mixed). An exchangeable correlation structure was specified. In the present data set the three repeated measurements were nested within farmers, within farms, so the farm and farmer ID were selected as subject variables, and visit number was selected as the within-subject variable. Statistical difference among the farm

tasks determined using confidence interval of Wald Statistics. A Bonferroni adjustment was applied to the conventional alpha level of 0.05 to control the overall type-1 error rate due to multiple tests, yielding a new alpha level of 0.002 (21). This is equivalent to considering overlap on the central 99.8% portion of the distribution for a metric, as calculated from the Wald statistic. All statistical analyses were conducted in Statistical Package for Social Sciences (SPSS v 23, IBM Corporation, New York, USA).

3.3- Results

A total of 91 posture measurements were gathered from 49 participants on 22 farms. Driving was the most frequently performed task on the farms.

3.3-1 Farm and farmer characteristics

Twenty-two family-owned farms participated in the study, including 16-grain farms, 2 animal farms, and 4 mixed-produce farms. A total of 48 male farmers and 1 female farmer were measured during their working tasks. The participant characteristics are shown in Table 4.

Table 3.4. Characteristics of farmers participating in field study of working posture

Farmer Characteristics (n=32)	Value
Age in years (Median, Min-Max)	52, 21-84
Sex (% Male)	98%
Body mass index (Median, Range)	28.6 Kg/cm ² , 20.11 Kg/cm ² - 41.39 Kg/cm ²
Height (cm) (Median, Range)	178 cm, 173 cm-183 cm
Weight (kg) (Median, Range)	90.00 Kg, 80.00-102.06
Years of farm work (Median, Range)	31.84, 2-70
Farm Characteristics (n=22)	
Acreage, acres (Median, Range)	4000, 960-12000
Commodity	
Grain crops % (N=16)	72.72%
Mixed % (N=04)	18.18%
Animal % (N=02)	9.09%

3.3-2 Work task measurements

Participants were measured up to three times for a total of 91 measurements (Figure 5). Working tasks were categorized into driving, manual, and mixed. Figure 5 shows the task distribution measured on the farms. Driving was the most commonly measured task (52%), and mixed tasks were least often measured (12%). The content of the task categories varied throughout the season. During the ‘spring’ (April and May) manual tasks included preparation such as machinery maintenance, planting for growing season, and animal herding. Driving in the spring consisted mostly of yard maintenance and equipment moving, only 1 mixed-task day was performed during these months.

In the ‘Summer’ months of June and July, driving tasks included seeding, spraying, and grain moving; Summer manual task included machinery and yard maintenance activities. The autumn harvest season (August to November) was the busiest time; long driving hours during the harvest season involved tractors, combines, swathers, grain trucks, pick-up trucks, ATVs, and skid-steers. Manual and mixed tasks were less common in harvest season, but when performed included: machinery fixing due to breakage or technical problem; canola testing before harvesting; driving for small tasks with several intervals such as pickup truck driving to town for short period of time; and grain truck driving from fields to farm.

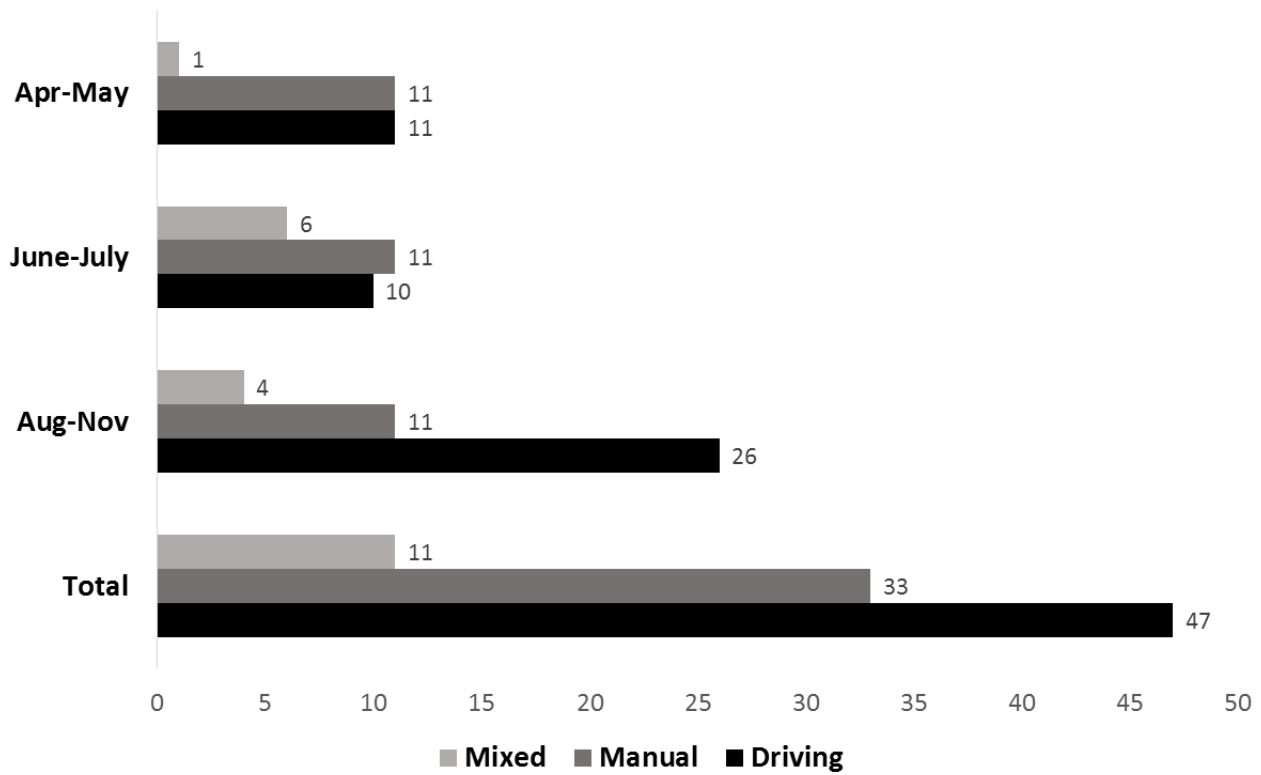


Figure 3.5. Seasonal Task Distribution in terms of number of measurements for three work task categories

3.3-3 Trunk Flexion-Extension Postures by Task

Table 5 illustrates the patterns of trunk flexion during driving, manual, and mixed tasks on farms. Manual tasks showed the highest median flexion-extension values, but the overall median flexion-extension values were not significantly different between tasks. The 90th percentile trunk flexion-extension was significantly higher for manual than driving tasks. Table 5 also presents the flexion-extension posture range between the 10th and 90th percentiles indicating the variability within tasks; this range was larger for manual and mixed tasks as compared to driving tasks.

3.3-4 Time in Neutral and Extreme Postures Trunk Flexion-extension

Working postures between 0° to 20° degrees were considered ‘neutral’ for both lateral and forward flexion; greater than 60° degrees was considered ‘extreme’ for forward flexion (Table5). Working time spent with trunk flexion-extension in extreme posture were not significantly different among driving, manual, and mixed task at the <0.002 level, however different trends were observed at the < 0.05 level, with the greatest proportion of extreme working posture spent during manual tasks, followed by mixed and driving tasks (Table 5).

3.3-5 Angular Speed Percentiles Flexion-Extension

The median and 90th percentile flexion-extension velocities were significantly lower for manual than driving tasks (Table 5). Time at low flexion-extension speeds (<5°/s %) showed approximately similar values for manual, driving, and mixed farm task. Time at high flexion-extension speeds (>90°/s %) also showed approximately similar values for driving, manual, and mixed farm tasks.

3.3-6 Neutral Periods and Rest: combining flexion-extension and lateral flexion data

The metrics ‘frequency of rest periods’ and ‘time spent at rest’ combine both flexion-extension and lateral flexion posture data; a posture is considered at ‘rest’ when neutral in both lateral and flexion-extension directions and <5°/s. Table 5 shows the frequency of periods spent in neutral posture for

flexion-extension and lateral flexion. All three farm tasks had a very similar frequency of rest periods: driving (2.1 periods/min), manual (2.06 periods/min) and mixed task (2.01 periods/min). However, the proportion of time spent at rest was approaching significance (i.e. at the 0.05 but not 0.002 level), with driving having the most time spent at rest followed by mixed and then manual tasks.

3.3-7 Trunk Lateral-Flexion postures by task

Lateral flexion exposure patterns for driving, manual, and mixed tasks are illustrated in Table 6. The 10th percentile lateral flexion angles were significantly lower during driving than manual task. Table 6 also presents the posture range between the 10th and 90th percentiles, indicating the variability within tasks; this range was larger for manual and mixed tasks as compared to driving tasks. Time in neutral lateral flexion (between -20° and +20°) was significantly higher in driving than manual tasks (Table 6).

3.3-8 Angular Speed Percentiles Lateral Flexion

The median lateral flexion angular velocities were similar between driving, manual, and mixed tasks. The lateral flexion median 90th percentiles were significantly different between driving and manual task, with the highest velocity for manual tasks, followed by mixed and driving tasks (Table 6).

Proportions of time at low lateral flexion speed (<5°/s for more than 3 s) and time at high lateral flexion speed (>90°/s) were approximately the same between the three farm tasks (Table 6).

Table 3.5. Median* and Interquartile Range (IQR) of flexion-extension metrics for farm tasks measured by I2M motion sensor (N=91)

Metrics	Driving	Manual	Mixed	Total
Number of Measures	47	33	11	91
Postural Displacement, Median and IQR				
Daily Mean	10.74 (6.43-14.98) (IQR of shift means)	15.31 (10.99-20.78)	11.61 (9.90-14.09)	12.20 (7.89-17.38)
Daily 10th percentile, °	-1.60 (-5.99-4.21)	-0.50 (-6.66-3.25)	-2.16 (-8.62-0.50)	-1.59 (-6.40-3.40)
Daily 50th percentile, °	9.12 (4.63-11.86)	12.26 (7.60-14.98)	9.52 (3.66-16.74)	9.74 (4.96-13.74)
Daily 90th percentile, °	21.68^b (17.28-30.75)	37.09^a (29.03-51.30)	34.54 (24.42-43.68)	29.29 (19.98-39.82)
Daily % Time in extreme (>60°)	1.09 (0.52-2.78)	3.91 (2.34-6.89)	3.02 (1.60-3.97)	2.35 (1.01-4.55)
Daily Frequency of 'periods (>3 s) in a neutral posture', min-1	2.1 (1.54-2.64)	2.06 (1.51-2.32)	2.01 (1.38-2.50)	2.06 (1.45-2.46)
Angular Speed, Median and IQR				
Daily Mean	6.14^b (5.00-7.02) (IQR of shift means)	8.56^a (6.95-9.96)	7.09 (6.60-7.99)	6.76 (5.84-8.29)
Daily 10th percentile, °/s	0.57 (0.49-0.65)	0.62 (0.54-0.76)	0.57 (0.52-0.61)	0.58 (0.52-0.68)
Daily 50th percentile, °/s	3.14 (2.51-3.72)	4.08 (3.32-5.46)	3.54 (3.14-4.49)	3.50 (2.65-4.34)
Daily 90th percentile, °/s	14.75^b (11.76-16.27)	21.52^a (17.27-24.42)	16.41 (15.85-19.62)	16.36 (14.48-20.20)
Daily % Time at low velocities (<5°/s for more than >3 s)	22.33 (11.68-33.66)	23.44 (16.81-27.94)	22.09 (12.37-27.71)	22.44 (13.45-29.88)
Daily % Time at high velocities (>90°/s)	0.06 (0.03-0.08)	0.18 (0.08-0.28)	0.14 (0.09-0.15)	0.08 (0.42-0.16)
Daily % Time at rest (<20° & <5°/s)	31.50 ^b (24.09-38.57)	19.34 ^a (14.46-24.91)	26.20 (14.64-30.46)	25.58 (17.09-34.15)

* Median of all 91 person-day exposure values for each metric (Bold text represents significant at $\alpha = 0.002$)^a The value is significantly different than driving at $\alpha = 0.002$, ^b The value is significantly different than manual at $\alpha = 0.002$

Table 3.6. Median* and Interquartile Range (IQR) of daily lateral flexion metrics for three farm tasks measured by I2M motion sensor (N=91)

Metrics	Driving	Manual	Mixed	Total
Number of measures	47	33	11	91
Daily mean*	0.69 (0.70-3.07) (IQR of shift means)	0.26 (-0.95-2.26)	0.32 (-1.30-2.42)	0.62 (-0.8-2.65)
Daily 10th percentile, °	-6.85^b,(-8.84- -5.34)	-11.76^a (-13.40 to -8.54)	-9.66 (-12.72 to -8.21)	-8.46 (-11.82 to -6.44)
Daily 50th percentile, °	1.04 (-0.67-3.37)	0.39 (-0.65-1.69)	0.56 (-1.55-2.12)	0.85 (-0.72-2.74)
Daily 90th percentile, °	8.58 (7.11-12.37)	12.95 (10.05-14.15)	12.43 (8.16-17.62)	10.84 (7.85-13.47)
Daily % Time in neutral (-20, +20°)	97.24^b (95.24-98.32)	92.19^a (89.74-95.19)	94.83 (86.21-95.90)	95.32 (92.01-97.62)
Angular speed				
Daily Mean*	6.09^b (5.23-7.33)	9.06^a (8.00-10.51)	8.35 (7.67-8.99)	7.42 (5.83-8.99)
Daily 10th percentile, °/s	0.63 (0.55-0.76)	0.76 (0.67-0.87)	0.63 (0.59-0.73)	0.67(0.57-0.78)
Daily 50th percentile, °/s	3.09 (2.35-3.72)	4.59 (3.24-5.99)	3.79 (3.61-4.58)	3.61 (2.57-4.58)
Daily 90th percentile, °/s	15.18^b (13.25-18.76)	24.04^a (20.90-25.99)	21.98 (20.43-22.34)	19.33 (14.68-23.51)
Daily % Time at low velocities (<5°/s for more than >3 s)	25.85 (15.58-37.23)	24.98 (15.81-28.22)	22.68 (13.77-29.45)	24.54 (15.66-32.90)
Daily % Time at high velocities (>90°/s)	0.03 (0.01-0.04)	0.05 (0.02-0.08)	0.09 (0.05-0.11)	0.04 (0.02-0.08)

*Medians are calculated from all 91 person-days for each metric (Bold text represents significant at $\alpha = 0.002$)

^a The value is significantly different than driving at $\alpha = 0.002$, ^b The value is significantly different than manual at $\alpha = 0.002$

3.4- Discussion

The present study documented 91 directly measured trunk posture measurements from 49 Saskatchewan grain and livestock farmers. Trunk postures were documented in terms of angular displacement and angular speed. Farming is a highly heterogeneous occupation with differences in both work tasks and farm characteristics across commodities. In the present study, a considerable distribution of exposures was found among the three types of farm tasks; driving (52%) was the most frequent task followed by manual (36%), and mixed (12%) tasks. Three out of 14 trunk flexion metrics and 4 out of 11 lateral flexion metrics were significantly different between tasks. The variability between tasks suggests that, even within the province of Saskatchewan, farm workers are not homogeneously exposed from day to day or throughout the year. Significant differences in farm tasks may stem from a wide range of factors: the unpredictable need for farm machinery maintenance/repair; available manufacturing skills and equipment (i.e., welding, carpentry); work requirements in different seasons; and weather conditions.

Driving was the most frequently measured task in the present study, which is not surprising given that many farm tasks in Saskatchewan are mechanized. Due to the short planting and harvesting seasons in Saskatchewan, farmers are required to drive for long durations during those seasons. During the short growing season, farmers have to perform farming activities such as seeding, spraying, and harvesting in a short time for large farm areas. The farms included in the present study consisted predominantly of grain production such as oil seeds, pulses, barley, and wheat crops. The machinery used for predominantly grain crops included: tractors; combines; grain trucks; pickup trucks; sprayers; all-terrain vehicles; skid steers; and swathers.

When considering the application of these results, the farming context may influence the type of work task, with differences in task make-up and proportion by commodity, season, geography, and

production methods. Farming also requires manual tasks, such as machinery maintenance, which may require more bending or awkward postures. Farm workers may be working in a remote setting where they are working independently on their farm tasks and thus have reduced capability to outsource work or get help, which may increase their exposure to awkward postures. In less mechanized situations, farmers in low-income regions depend on more manual work which may increase their exposure time to awkward working postures. The Food and Agriculture Organization of the United Nations (FAO) has been encouraging farmers in lower-income regions to purchase farm machinery to improve their economy, but these regions are still less mechanized as compared to the developed world (22). Increasing mechanization in developing regions may bring their exposures more in line with those observed in highly mechanized grain and livestock production.

3.4-1 Trunk posture in farming as compared to other industries

When comparing to other jobs considered to be manually intensive, farmers in the present study spent more time in neutral posture (62%) than car disassembly workers (9.5 %) (19), but slightly less than airline baggage handlers (71%) (23). Farm workers in the present study showed lower 10th (-1.59° over all tasks) and 50th percentile (10° overall task) flexion-extension as compared to stud welders (-9.0° and 30.6°, respectively)(24), but similar to aircraft baggage handlers (23). Mixed heavy industrial workers (25) showed slightly higher 10th (0.14°) percentile flexion extension than the farm workers in the present study. The farm workers' 90th percentile values (29.3° over all tasks) were consistently lower than car disassembly workers (40.2°) (19), airline baggage handlers (34.1°) (23), mixed heavy industrial workers (40.3°)(25), and stud welders (81.7°)(24). Forward flexion more than 60 degrees is considered an 'extreme' posture, and farmers in the present study spent less time in extreme posture (2.4% over all tasks) than car disassembly workers (28%) (19), or stud welders (40.1%) (24), which may be related to the nature of farm tasks compared to other heavy industries.

In farming, driving and manual tasks demonstrate less flexion-extension as compared to a previous study of five heavy industries (25) assessing various manual tasks. The frequency per minute of periods longer than 3 seconds in a neutral posture was higher for the farm workers in the present study (2.06) than baggage handlers (23) (1.6) and car disassembly workers (1.5) (19), which means that farm workers have more opportunities to recover in neutral posture as compared to the other occupations.

Farmers in the present study had a greater proportion of rest time and time at low velocities than either car disassembly workers (25) or airport baggage handling (23), and lower velocities than mixed heavy industrial occupations (19). The velocity 50th and 90th percentile for air baggage handlers is higher than farm workers which may be due to baggage handlers' working days comprised of a number of active working periods which increase the motion/speed. (23) According to Teschke et al., mean, 10th, and 90th percentile flexion-extension speed or velocity is higher for construction carpenters, constructing laborers, and floor layers than for transportation workers, likely due to the increased machinery operation in transportation occupations.(25) Similarly, farmers often perform machinery operation (52% of measurements in the present study). The nature of manual farming tasks may also have an influence on velocity; machinery maintenance and repair tasks tend to involve more static or sustained postures, which results in decreased movement speed. Farmers may also have fewer short-term time constraints when compared to aircraft baggage handlers, although they often have longer working hours (23).

3.4-2 Considering implications for farmers' health

Although it was not the purpose of the present study to investigate the association between awkward posture and LBD, several previous studies have investigated this issue and reported exposure levels which are associated with increased risk of LBD. For example, Coenen et al. conducted a large prospective cohort study on the relationship of cumulative low back load and

LBD, and found that spending more than >5% of the time during 8 hours work day with forward flexion greater than >60° more than doubled the risk of developing LBD (OR 2.35, 95% CI 1.46-3.79) (26). Hoogendoorn et al. conducted a cohort study on 34 industries in the Netherlands(7) and reported an increased, but non-significant, risk (RR 1.5, 95%CI 0.90-2.42) of LBD for workers with trunk forward flexion greater than 60° for 5% of the working time.(7) The present study on farm workers found only 2.35% of farmers' time was spent in these extreme trunk flexion postures, indicating a lower risk level (7,26).

Punnett et al. studied the relationship between awkward working posture and LBD through case-referent study and defined trunk posture in three categories (27). Forward-flexion less than 20° was considered neutral posture, 21° to 45° considered 'mild' forward flexion, and greater than 45° forward flexion considered 'severe' (27). Punnett et al. reported 4 times higher risk (OR 4.2, p-value 0.014) for workers who spent 0 to 10% of the working time in mild (>20°) forward flexion, and 6 times higher risk (OR 6.1, P-value 0.014) for workers who spent >10% of the working time in mild (>20°) forward flexion (27). In the present study, farm workers spent 62% of the time between 0° to 20° and 38% greater than 20°; suggesting an increased risk of at least 6-fold increase (27). Punnett et al. also reported that lateral bending more than 20° for more than 10% of the working time increases the risk of LBD about 4 times (OR 3.8, p-value 0.42) (27). In the present study, the median 95% time was spent laterally bent less than 20°, indicating a lower risk category according to Punnett et al. (27).

While trunk posture is an important predictor of LBD, it is not the only work exposure which may contribute to LBD among farmers. Research investigating computer related activities found that sitting for more than 5 hours/day increased the risk of LBD (OR 1.8, 95% CI 1.0-1.3)(28), a consistent result across several studies (29,30). Farm workers' exposure to extended sitting during

long driving tasks could increase their risk of developing LBD independent of trunk bending, as could their exposure to whole body vibration (WBV) during driving. WBV has been shown to be related to back pain among farmers (OR 2.44, 95%CI 0.95-6.43) (31). Trunk rotation is also an important risk factor for LBD, and farmers may be twisting or rotating during driving tasks. Punnett et al. reported twisting or rotating as a risk factor for LBD (OR 5.7, 95% CI 1.1-28.1) (27).

Considering previous epidemiological work from other industries, it appears that Saskatchewan farmers, in general, have lower postural exposure than some previously studied heavy industries. However, farmers also have exposure to other risk factors which may contribute to their risk for LBD such as WBV and prolonged sitting with or without rotation. One could hypothesize that this is related, in part, to why LBD rates are higher in farming even though the awkward postures are not the highest when compared to other industries. Indeed, a prior systematic review examining the general working population reported that awkward occupational posture on its own is likely not a causal risk factor for LBD, and that other risk factors need to be considered with working posture (12). This study was not able to account for all work-related risk factors for LBD, but these exposures, and their combination, could be considered in future research.

3.5- Strengths and limitations

In the present study, a direct measurement method was used to measure the awkward working posture in farm workers. The strength of the study is that this is the first field-based ergonomic assessment of Saskatchewan farm workers and among the first investigating highly-mechanized grain commodities. Direct exposure measurement is expensive, but considered the most valid and reliable tool (32) which overcomes the limitations of subjectivity and recall bias (33).

There are also some limitations in the present study. The study sample was not selected randomly. The participants were recruited based on convenient sampling of farm workers who were willing to

participate in the study. Caution should be taken in terms of generalization to all farm workers due to non-randomized selection of study participants. The present study directly measured posture using I2M motion sensors among Saskatchewan farm workers. The light weight of I2M motion sensors allowed for easier use by farm workers without interrupting regular work activities.

Unfortunately, the farm work environment did not support the collection of magnetometer data due to the ferromagnetic metals and electronic equipment, and so trunk rotation was not measured. The study captured a few hours of exposure, and due to practical reasons could not measure the whole working day (often more than 12 hours). The present results cannot be generalized to all farmers due to heterogeneity in this global industry, but may apply to large-scale grain and livestock farms in a highly-mechanized, high-income context of North American and European/Eurasian plains. The present study had a sample of 49 farm workers, which may not be representative of Saskatchewan farmers. Furthermore, participants may be more health-and-safety-conscious and interested in back health as compared to non-participants. The present study results cannot be generalized to female farm workers; most study participants were men, but according to Statistics Canada, 23% of Saskatchewan farm operators are women (34). Furthermore, in the larger SFIC which used a stratified sampling frame, 40% of the participants were women (35). The average age of the farm workers in the present study (52 years) was similar to the SFIC study (54 years) (35).

3.6- Conclusion

This study documented farmers' trunk posture exposures during driving, manual, and mixed tasks, describing posture exposure patterns for angles and speed in terms of frequency, duration, and level. Driving was the most frequently-measured task and tended to have the lowest working postural exposures. While angles and velocities are overall within guidelines (19), linking the findings of the present study with previous epidemiological studies showed farm workers might be at higher risk for LBD as a result of working in non-neutral posture for long durations. The results of the study

provide a foundation for prevention efforts. Future epidemiological studies should incorporate assessment of trunk rotation and WBV to provide a more complete picture of occupational exposures.

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Chapter 4: General Discussion and Conclusion

This thesis explores exposure to awkward working posture as a risk factor for low back disorders (LBD) in farmers. Existing evidence on the association between awkward working posture and LBD in farmers was examined with a systematic literature review (manuscript 1). The directly-measured exposure patterns of awkward working posture in Saskatchewan farmers are described in manuscript 2. This discussion chapter provides the final overview of manuscripts 1 and 2, as well as overall recommendations, implications for future research, strengths and limitations, and final conclusions of the research.

4.1- Manuscript 1: The systematic review

The review manuscript focused on awkward posture as a risk factor for LBD among farm workers. A number of epidemiological studies and reviews have been conducted on musculoskeletal disorders in farm workers including LBD, but to date no systematic review has focused on awkward working posture as a risk factor for LBD among farmers. Due to seasonality, employment context, and various geographical distribution farm workers are likely to have unique exposure patterns to awkward posture as compared to other occupations.

This systematic review was performed using two conceptual group of terms ‘low back disorders’ and ‘farmer’ to search 6 online databases. Screening, data extraction, and quality assessment were performed by two reviewers independently, with a third party for determining consensus when needed. Included articles were English language full-text studies with an inferential test quantifying the association between posture exposure and LBD (a broad term that includes low back injuries, low back pain, sciatica, and spine-related arthritis) as an outcome. Data extraction included demographic, sampling strategy; study design; LBD case definition; and exposure dimensions of level, frequency, and duration.

The systematic review identified nine articles that assessed the association between awkward working posture and LBD in farm workers (1,4–11). Six studies found a positive association between awkward posture and LBD (1,5–7,10,11). Two studies showed a non-significant association between awkward posture and LBD (8,9), and one study showed a protective effect (4). The studies also had considerable variability in the study context, geographical location, statistical approaches, and farm commodity. Despite this variability, the weight of evidence suggests there is an association between awkward posture and LBD.

4.2- Methodological Considerations

4.2-1 Methods of exposure assessment used by the studies

In general, the studies included in the present review had low precision of exposure assessment; all of the studies used self-report methods to determine the exposure of awkward working posture (1,4–11). Self-report methods have low reliability and validity as compared to direct exposure measurement method (13). Direct exposure measurement can provide more reliable data for occupational exposure assessment and is also an ideal choice for ergonomic evaluation (13). However, in the present review, no study used direct exposure measurement to determine occupational awkward working posture.

Definitions of LBD and reported prevalence period were different across the studies. In the present review, most of the included studies used standardized questionnaire instruments (such as Standardized Nordic Questionnaire) to measure the LBD (1,4–11). These questionnaires have been tested for their reliability (1,4–10) but there are also limitations of these cross-sectional questionnaires, such the inability to determine incidence. The present review showed diversity in terms of sampling strategy, study design, prevalence periods, LBD case definition, and exposure assessment methods, which made direct comparison difficult and precluded meta-analysis. A review

conducted by Osborne et al. reported the same limitations, and suggested that this limits generalizability of results (14).

4.2-2 Strengths and limitations

The main strength of the present review is that it is the first time a review has been conducted on the association between awkward posture and LBD in a farming population. The sensitivity analysis is also conducted to confirm the association between awkward posture and LBD. The review provides detailed information on the current literature in terms of exposure assessment methods, exposure categories, employment context, and characteristics of the study population. The search for included studies was done comprehensively and screened thoroughly using inclusion criteria (15). In addition, risk of bias was assessed based on published tools (16).

The review also has some limitations. The review found few studies, and studies were not excluded based on quality or high risk of bias. Studies with high risk of bias were also included in the review, which may lead to less reliable results (17). Eliminating studies based on quality is not always desirable; considering a wide range of studies has been recommended in the realm of public health so as to make decisions based on all available evidence (18,19). The present review included only English language articles, so review findings may be impacted by language bias. A recent English-language review conducted on LBD in farm workers reported a bias towards high-income nations disproportionate to the global farming workforce; these results may be related to language restrictions (20).

4.3- Manuscript 2: Trunk posture exposure patterns

The systematic review described in manuscript 1 described a literature gap in relation to field-based studies of directly-measured awkward posture in farmers. Since direct measurement can be costly and challenging for large-scale epidemiological studies, a field-based feasibility pilot makes a natural

first step. Thus, the focus of manuscript 2 was to conduct direct exposure measurement to assess trunk posture exposure patterns in Saskatchewan farmers. The direct exposure measurement was performed using data-logging I2M motion sensors to assess the trunk posture, yielding 91 measurements among 49 farm workers working at 22 farms. The study categorized the farm working tasks into driving, manual, and mixed tasks throughout spring, summer, and fall seasons. Driving was the most-commonly performed task throughout all the seasons, and a greater proportion of driving tasks were performed during August to November due to the harvesting season.

The data from the trunk mounted posture sensors in the present study were analyzed descriptively with medians and interquartile range. Generalized Estimation Equation (GEE) was used to identify statistical differences between the farm tasks. The findings indicated that the median trunk flexion-extension is greater for manual tasks as compared to driving and mixed tasks. These values were not significant based on Bonferroni α level <0.002 , but did have a p level < 0.05 . Similarly, 90th percentile flexion-extension was significantly higher for manual than driving task. These results showed that in general, there is more flexion-extension during manual tasks than in driving. This makes intuitive sense, since manual tasks require more repeated or sustained bending when handling objects, maintaining machinery, or caring for animals at ground level.

The Saskatchewan farm setting likely impacted the reported postures. Farm workers in Saskatchewan may be less likely to outsource farm tasks due to working and living in remote settings (28). They perform most of the farm tasks independently, which may increase their exposure time in an awkward posture. Long driving hours were required during the harvesting season, and high levels of mechanization of farm work results in more driving tasks. In low-income nations, farmers may still rely on more traditional farming practices consisting of more manual tasks which may increase

their exposure to working in awkward postures. Measurements from the present study are expected to be unrepresentative of such farming practices.

For metrics such as percent time spent flexed more than 20°, the Saskatchewan farmers' exposure is anticipated to have an impact on their low back health. Previous studies have shown that working with $\geq 45^\circ$ or $\geq 60^\circ$ forward bending increased the risk of LBD (31). The farm workers showed low velocities as compared to other occupational groups such as car disassembly workers (29), airport baggage handlers (32), and mixed heavy industrial occupations (33). In the present study, farmers spent a higher proportion of their measured work time (52%) driving machinery, which involved short breaks and long hours sitting, especially when compared to car disassembly and baggage handling. Farm workers' manual tasks includes machinery maintenance and other repair work which may require working in low speed and more in a static posture. Even though postural exposures are lower than many heavy industries, the sum of farming exposures (including physical factors like prolonged sitting and whole body vibration as well as psychosocial factors) may be contributing to the elevated rates of LBD observed in farmers.

4.4- Methodological Considerations

4.4-1 Sampling Strategy

A convenience sampling strategy was used to measure 49 farm workers recruited from 22 farms. Sixty farms were contacted through mailed letters from Saskatchewan Farm Injury Cohort Study participant list (28). The farms were recruited within 400 kilometers of Saskatoon due to some practical issues such as traveling time to farms for data collection and researcher safety. However, farms outside this area may have different farming practices and commodities, such as poultry and swine farms which were not measured in the present study. The recruited 22 farms are unlikely to be

representative of the whole province of Saskatchewan with its 36,953 farms, as reported by the Agriculture Census (46). The farmers participated based on their interest and availability which may have introduced selection bias. Participants who already have back pain might have been more likely to participate in the study, or alternatively those who were less busy on the farm might have been more amenable to a day-long visit from researchers.

4.4-2 Trunk posture exposure assessment methods

Many epidemiological studies on LBD (including all those in the systematic review) determine the presence or absence of potential risk factors through self-report. Unfortunately, this method makes it difficult to quantify the level or magnitude of the potential risk factor, or the level at which the risk factor becomes a problem.

Very few field-based research studies using direct measurement approaches have been conducted for biomechanical exposures, but this level of detail is necessary to understand the association between low back disorder risks and biomechanical variables (34). Marras et al. (1995) conducted an early direct measurement study with a case-control design, and quantitatively monitored 114 different workplace variables in more than 400 jobs (35). They analyzed many previously unexplored biomechanical workplace factors such as trunk velocities (35). They used a multivariate logistic regression model for five risk factors in a combination of lateral velocity, sagittal torso bending angle, twisting velocity, external force movement, and lifting frequency and found that as the magnitude of these factors has increased, the risk of LBD has significantly increased (35). This study by Marras provided the means to quantify how much exposure is too much over a range of biomechanical metrics and expanded our understanding of LBD development. More longitudinal studies with detailed biomechanical measurements are needed to investigate posture as a causal risk factor for LBD, and over an expanded range of job tasks.

The present study used direct measurement with motion sensors (I2M motion sensors) to measure trunk posture; these were light and did not affect the participants' working schedule. The measurements were performed in a naturalistic setting; the researcher showed up on the farm and placed the posture sensors on participants' bodies and followed farm workers throughout the day as they performed their regular farm tasks. At the end of the day, the posture sensor was removed and the data processed through computer software for analysis. The farm workplace did not allow for magnetometer data collection due to ferrous material in the farm working environment such as metal material and running machinery (tractors and other farm machinery). As a result, the present study could not measure trunk rotation in farm workers. However, trunk rotation is an important risk factor for LBD; Hoogendoorn et al. reported that trunk rotation in $<30^\circ$ for longer than 10% of working time increased the risk of LBD (RR 1.3, 95%CI 0.9-1.9) (36).

4.5- Study implications and future directions

Manuscript 1 identified gaps in research regarding the association between awkward working posture and LBD. Future research should incorporate direct exposure measurement, prospective cohort studies, and standardized LBD definitions. A better understanding of the association between working in an awkward posture and LBD will help in developing intervention strategies to reduce the disability and loss of productivity in farm workers.

Manuscript 2 focused on direct exposure measurement of trunk posture in Saskatchewan farm workers. Relatively little research has been conducted on trunk awkward posture exposure with direct exposure method in farm workers, and no study to date was conducted on trunk posture exposure among Saskatchewan farmers. The present study provides an important trunk posture exposure profile for Saskatchewan farmers and demonstrates the feasibility of direct measurement on farms, which contributes to a foundation for future research. Future research focusing on

ergonomic risk factors for LBD should consider larger sample sizes to ensure representativeness of the farm workers. Female farm workers in particular should be included in future studies commensurate with their numbers in the workforce. Research on interventions to reduce the risk factors for LBD (including awkward trunk posture) in farm workers is required to contribute to evidence-based prevention strategies for farm workers. The present study found the highest percentage of time spent during driving. No study was found evaluating interventions for long driving hours among farmers, but it is commonly advised that the effect of long driving hours may be reduced by taking short breaks during busy harvesting season. Future research can also work on the application of smart phone and other technology developments (wearable devices such as ‘fitbit’) for appropriateness and validity to collect data on awkward postures. Technological developments are moving towards low-cost methods with high precision which may be feasible to study a large number of workers within naturalistic occupational settings.

4.6- Recommendations for future research.

Quantitative exposure-response relationships between working in awkward posture and LBD based on field studies among farmers are needed. The following are recommendations to strengthen future research in this area:

- 1- LBD case definition standardization among researchers can improve comparative analysis and research practices. For example, Clermont et al suggested that the standardized LBD definition should include the site of the LBD, observed symptoms, time frame of the measure with frequency and duration of symptoms, and measure of severity (31).
- 2- Self-report has relatively low reliability and validity. If feasible, future studies should include direct exposure measurement to assess detailed exposure patterns.

3- Due to an increasing proportion of women in the farming workforce, researchers should also focus on women's roles by stratified sampling to ensure more equitable representation of the farming occupation.

4- In order to facilitate meta-analysis and avoid study heterogeneity in future reviews of the association between working awkward posture and LBD, researchers should consider more standardized exposure categories, metrics, and statistical approaches.

5- To reduce the risk of bias, future studies should consider an appropriate sampling frame. Random sampling techniques should be used to improve the population representation and to reduce the risk of bias.

4.7- Knowledge translation of thesis

An earlier version of Manuscript 1 results were presented at the Saskatchewan Epidemiology Symposium (SEA) held in Regina Saskatchewan in 2015. Manuscript 2 findings are part of the Saskatchewan Farmers Back Study brochure sent out to participating farms (47). The Saskatchewan Farmers Back Study team members also conducted meetings with a stakeholder advisory group before and after completion of data collection as part of an integrated knowledge translation approach (48). Preliminary results were disseminated and discussed with stakeholder advisory group members in a second meeting. Finally, Manuscript 2 results were presented at the 2016 Saskatchewan Epidemiology Association (SEA) and the 2016 Canadian Association for Research on Work and Health (CARWH). Manuscript 1 will be submitted to the Journal of Agromedicine and manuscript 2 will be submitted to Journal of Applied Ergonomics.

4.8- Conclusion

This thesis synthesized the evidence on the association between awkward working posture and LBD and assessed the trunk posture exposure patterns in Saskatchewan farm workers. The review found

that the weight of evidence suggests an association between awkward working posture and LBD in farm workers. Prospective cohort studies and direct exposure measurement are recommended to provide better understand the association between awkward working posture and LBD. The direct measurement of farmers' trunk posture added a unique contribution by measuring three broad farm activities: driving, manual, and mixed tasks. Comparing the study findings with previous epidemiological research, farm workers have lower postural exposures than many industries but may be at higher risk of LBD due to long durations of non-neutral posture. The results of both studies can contribute to future epidemiological studies and development of intervention strategies to improve the back health of the farming populations. Further research on physical risk factors such as lifting, manual material handling, long driving exposure, and twisting, as well as personal and psychosocial factors will provide a more comprehensive understanding of LBD risk factors in farm workers.

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APPENDIX-1: Systematic review search terms and data base

Tables

Table 1: OVID Medline (1950 to present) search strategy.

'Low Back Disorder' search terms	'Farming' search terms
<ol style="list-style-type: none"> 1. low back pain/ 2. (Musculoskeletal adj4 (symptom* or injur* or disorder* or pain or dysfunction* or problem* or complaint*)).ab,ti. 3. ((orthopedic or orthopaedic) adj4 (injur* or problem* or disorder* or dysfunction*)).ab,ti. 4. exp Musculoskeletal Diseases/ 5. "Muscle strain*".ab,ti. 6. back/ or lumbosacral region/ or sacrococcygeal region/ 7. spine/ or coccyx/ or intervertebral disc/ or lumbar vertebrae/ or sacrum/ or exp spinal canal/ or thoracic vertebrae/ 8. (spine or spinal or coccyx or "intervertebral disc" or lumbar vertebrae or sacrum or "spinal canal" or "thoracic vertebrae").ab,ti. 9. (back or "lumbosacral region" or "sacrococcygeal region").ab,ti. 10. 3 or 4 or 5 11. 6 or 7 or 8 or 9 12. 10 and 11 13. Sciatica/ 14. sciatica.ab,ti. 15. lumbago.ab,ti. 16. (hip adj2 pain).ab,ti. 17. (lumbar adj pain).ti,ab. 18. Dorsalgia.ti,ab. 19. coccydynia.ti,ab. 20. spondylosis.ti,ab. 21. discitis.ti,ab. 22. (disc adj degeneration).ti,ab. 23. (disc adj prolapse).ti,ab. 24. (disc adj herniation).ti,ab. 25. (facet adj joints).ti,ab. 26. Intervertebral Disc/ 27. arachnoiditis.ti,ab. 28. Spinal Fusion/ 29. postlaminectomy.ti,ab. 30. (Back adj (injur* or disorder* or pain or dysfunction* or problem* or ache*)).ab,ti. 31. Backache*.ti,ab. 32. Back Pain/ 33. (failed adj back).ti,ab. 34. (low* adj back).ti,ab. 35. 1 or 2 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 	<ol style="list-style-type: none"> 36. "Farmer*".ab,ti. 37. "Agricultural worker*".ab,ti. 38. "Farm worker*".ab,ti. 39. "Breeder*".ab,ti. 40. "Cultivator*".ab,ti. 41. "Grower*".ab,ti. 42. "Harvester*".ab,ti. 43. Plowman.ab,ti. 44. "Sower*".ab,ti. 45. "Tiller*".ab,ti. 46. "Agronomist*".ab,ti. 47. Stockman.ab,ti. 48. Stockmen.ab,ti. 49. (Stockperson or stockpersons).ab,ti. 50. (Stock person or stock persons).ab,ti. 51. "Granger*".ab,ti. 52. (Herdsman or herdsman).ab,ti. 53. (Herds person or herds persons or herds person or herds persons).ab,ti. 54. "Agriculturalist*".ab,ti. 55. "Shepherd*".ab,ti. 56. Farming.ab,ti. 57. "Producer*".ab,ti. 58. agriculture/ or agricultural irrigation/ or animal husbandry/ or aquaculture/ or beekeeping/ or dairying/ or gardening/ or hydroponics/ or organic agriculture/ 59. Agricultural Workers' Diseases/ 60. sheep shear*.mp. 61. livestock worker*.mp. 62. tractor*.mp. 63. farmworker*.ab,ti. 64. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 65. or/36-64
<ol style="list-style-type: none"> 66. 35 and 65 67. limit 64 to (English language and humans) 	

Table 2: OVID EMBASE (Excerpta Medica & EMBASE Classic; 1947 to present) search strategy.

'Low Back Disorder' search terms	'Farming' search terms
1. low back pain/ 2. (Musculoskeletal adj4 (symptom* or injur* or disorder* or pain or dysfunction* or problem* or complaint*)).ab,ti. 3. ((orthopedic or orthopaedic) adj4 (injur* or problem* or disorder* or dysfunction*)).ab,ti. 4. exp musculoskeletal disease/ 5. muscle strain/ 6. exp musculoskeletal injury/ 7. 3 or 4 or 5 or 6 8. back/ or back muscle/ or exp spine/ 9. lumbosacral region.ti,ab. 10. sacrococcygeal region.ab,ti. 11. coccygeal bone/ 12. (spine or spinal or coccyx or "intervertebral disc" or lumbar vertebrae or sacrum or "spinal canal" or "thoracic vertebrae").ab,ti. 13. (back or "lumbosacral region" or "sacrococcygeal region").ab,ti. 14. 8 or 9 or 10 or 11 or 12 or 13 15. 7 and 14 16. ischialgia/ 17. lumbago.ab,ti. 18. (hip adj2 pain).ab,ti. 19. (lumbar adj pain).ti,ab. 20. Dorsalgia.ti,ab. 21. coccydynia.ab,ti. 22. spondylosis/ or cervical spondylosis/ 23. diskitis/ 24. (disc adj degeneration).ti,ab. 25. (disc adj prolapse).ti,ab. 26. (disc adj herniation).ti,ab. 27. (facet adj joints).ti,ab. 28. intervertebral disk/ 29. arachnoiditis/ 30. spine fusion/ or anterior spine fusion/ or posterior spine fusion/ or spondylodesis/ 31. postlaminectomy.ti,ab. 32. (Back adj (injur* or disorder* or pain or dysfunction* or problem* or ache*)).ab,ti. 33. Backache*.ti,ab. 34. backache/ or discogenic pain/ or failed back surgery syndrome/ or low back pain/ 35. backache/ or discogenic pain/ or failed back surgery syndrome/ 36. back pain*.ab,ti. 37. (failed adj back).ti,ab. 38. (low* adj back).ti,ab. 39. 1 or 2 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38	40. farmer*.ab,ti. 41. agricultural worker/ 42. agricultural worker*.ab,ti. 43. Farm worker*.ab,ti. 44. breeder*.ab,ti. 45. cultivator*.ab,ti. 46. grower*.ab,ti. 47. harvester.ab,ti. 48. plowman.ab,ti. 49. sower*.ab,ti. 50. tiller*.ab,ti. 51. agronomist*.ab,ti. 52. (stockman or stockmen or stockperson or stockpersons).ab,ti. 53. (stock person or stock persons).ab,ti. 54. granger*.ab,ti. 55. (Herdsman or herdsmen).ab,ti. 56. (Herds person or herdsperson or Herds persons or herdspersons).ab,ti. 57. agriculturalist*.ab,ti. 58. shepherd*.ab,ti. 59. farming.ab,ti. 60. producer*.ab,ti. 61. agriculture/ or exp agricultural parameters/ 62. animal husbandry/ or cattle farming/ or dairying/ or pig farming/ or poultry farming/ or sheep farming/ 63. "irrigation (agriculture)"/ 64. agricultural procedures/ or exp agricultural inoculation/ or agricultural management/ or agronomy/ or apiculture/ or exp aquaculture/ or exp crop production/ or farming system/ or harvesting/ or exp horticulture/ or molecular farming/ or monoculture/ or natural fiber production/ or organic farming/ or precision agriculture/ or sericulture/ or species cultivation/ or sustainable agriculture/ or tillage/ or viniculture/ 65. gardening/ 66. sheep shear*.ab,ti. 67. livestock worker*.ab,ti. 68. tractor/ or tractor driver/ 69. farmworker*.ab,ti. 70. or/40-69
71. 39 and 70 72. limit 64 to (English language and humans)	

Table 3: CINAHL (1937 to present) search strategy.

'Low Back Disorder' search terms	'Farming' search terms
<ol style="list-style-type: none"> 1. (MH "Low Back Pain") 2. TI (Musculoskeletal N2 (symptom* or injur* or disorder* or pain or dysfunction* or problem* or complaint*)) OR AB (Musculoskeletal N2 (symptom* or injur* or disorder* or pain or dysfunction* or problem* or complaint*)) 3. TI ((orthopedic or orthopaedic) N2 (injur* or problem* or disorder* or dysfunction*)) OR AB ((orthopedic or orthopaedic) N2 (injur* or problem* or disorder* or dysfunction*)) 4. (MH "Musculoskeletal Diseases+") OR (MH "Musculoskeletal Abnormalities+") 5. TI muscle n1 strain* OR AB muscle n1 strain* 6. (MH "Back") 7. TI lumbosacral N1 region* OR AB lumbosacral N1 region* 8. TI sacrococcygeal region OR AB sacrococcygeal region 9. (MH "Spine") OR (MH "Coccyx") OR (MH "Intervertebral Disk") OR (MH "Lumbar Vertebrae") OR (MH "Sacrum") OR (MH "Spinal Canal") OR (MH "Thoracic Vertebrae") 10. TI (spine or spinal or coccyx or "intervertebral disc" or lumbar vertebrae or sacrum or "spinal canal" or "thoracic vertebrae") OR AB (spine or spinal or coccyx or "intervertebral disc" or lumbar vertebrae or sacrum or "spinal canal" or "thoracic vertebrae") 11. TI back OR AB back 12. 3 OR 4 OR 5 13. 6 OR 7 OR 8 OR 9 OR 10 OR 11 14. S12 AND S13 15. (MH "Sciatica") 16. TI Sciatica OR AB Sciatica 17. TI lumbago OR AB lumbago 18. TI hip N2 pain OR AB hip N2 pain 19. TI lumbar N1 pain OR AB lumbar N1 pain 20. TI Dorsalgia OR AB Dorsalgia 21. TI coccydynia OR AB coccydynia 22. (MH "Spondylosis") OR (MH "Spondylolysis") 23. TI discitis OR AB discitis 24. TI "disc degeneration" OR AB "disc degeneration" 25. TI "disc prolapse" OR AB "disc prolapse" 26. TI "disc herniation" AND AB "disc herniation" 27. TI "facet joints" OR AB "facet joints" 28. (MH "Intervertebral Disk") 29. TI arachnoiditis OR AB arachnoiditis 30. (MH "Spinal Fusion") 31. TI postlaminectomy OR AB postlaminectomy 32. TI (Back N1 (injur* or disorder* or pain or dysfunction* or problem* or ache*)) OR AB (ack N1 (injur* or disorder* or pain or dysfunction* or problem* or ache*)) 33. TI Backache* OR AB Backache* 34. (MH "Back Pain") OR (MH "Failed Back Surgery Syndrome") 35. TI failed N1 back OR AB failed N1 back 	<ol style="list-style-type: none"> 38. (MH "Farmworkers") 39. TI farmer* OR AB farmer* 40. TI Agricultural N1 worker* OR AB Agricultural N1 worker* 41. TI Farm N1 worker* OR AB Farm N1 worker* 42. TI farmworker* OR AB farmworker* 43. TI breeder* OR AB breeder* 44. TI cultivator* OR AB cultivator* 45. TI grower* OR AB grower* 46. TI harvester* OR AB harvester* 47. TI plowman OR AB plowman 48. TI sower* OR AB sower* 49. TI tiller* OR AB tiller* 50. TI agronomist* OR AB agronomist* 51. TI (stockman or stockmen or stockperson) OR AB (stockman or stockmen or stockperson) 52. TI "stock person" OR AB "stock person" OR TI "stock persons" OR AB "stock persons" 53. TI Granger* OR AB Granger* 54. TI (Herdsman or herdsmen) OR AB (Herdsman or herdsmen) 55. TI ("Herds person" or herdsperson or "Herds persons" or herdspersons) OR AB ("Herds person" or herdsperson or "Herds persons" or herdspersons) 56. TI Agriculturalist* OR AB Agriculturalist* 57. TI Shepherd* OR AB Shepherd* 58. TI Farming OR AB Farming 59. TI Producer* OR AB Producer 60. (MH "Agriculture") OR (MH "Horticulture") 61. TI "animal husbandry" OR AB "animal husbandry" 62. TI aquaculture OR AB aquaculture 63. TI beekeeping OR AB beekeeping 64. TI dairying OR AB dairying 65. TI hydroponics OR AB hydroponics 66. TI ("Agricultural Workers' Diseases" OR "Agricultural Workers' Disease") OR AB ("Agricultural Workers' Diseases" OR "Agricultural Workers' Disease") 67. TI sheep N1 shear* OR AB sheep N1 shear* 68. TI livestock N1 worker* OR AB livestock N1 worker* 69. TI tractor* OR AB tractor* 70. S38 OR S39 OR S40 OR S41 OR S42 OR S43 OR S44 OR S45 OR S46 OR

36. TI low* N1 back OR AB low* N1 back 37. 1 OR 2 OR 14 OR 15 OR 16 OR 17 OR 18 OR 19 OR 20 OR 21 OR 22 OR 23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29 OR 30 OR 31 OR 32 OR 33 OR 34 OR 35 OR 36	S47 OR S48 OR S49 OR S50 OR S51 OR S52 OR S53 OR S54 OR S55 OR S56 OR S57 OR S58 OR S59 OR S60 OR S61 OR S62 OR S63 OR S64 OR S65 OR S66 OR S67 OR S68 OR S69
71. 37 and 70 72. limit 71	

Table 4: Web of Science with Conference Proceedings (WOS SCI: 1899 - present; SSCI: 1956-present; A&HCI: 1975-present ; CPSI-S: 1990-present; CPSI-SSH: 1990-present) search strategy.

'Low Back Disorder' search terms	'Farming' search terms
<ol style="list-style-type: none"> 1. Topic=("low back pain" or "back pain" or backache) OR Topic=(low* NEAR/1 back) OR Topic=(failed NEAR/1 back) 2. Topic=(Back NEAR/1 (injur* or disorder* or pain or dysfunction* or problem* or ache*)) TS=(Musculoskeletal NEAR/4 (symptom* or injur* or disorder* or pain or dysfunction* or problem* or disease* or complaint*)) OR TS=((orthopedic or orthopaedic) NEAR/4 (injur* or problem* or disorder* or dysfunction*)) OR TS=(muscle NEAR/1 strain*) 3. TS=(lumbosacral region or sacrococcygeal region or back or spine or coccyx or "intervertebral disc" or "lumbar vertebrae" or sacrum or "spinal canal" or "thoracic vertebrae") 4. #8 AND #7 Topic=(sciatica or lumbago or dorsalgia or coccydynia or discitis or "facet joints" or "intervertebral disc" or arachnoiditis or "spinal fusion" or postlaminectomy) OR Topic=(hip NEAR/2 pain) OR Topic=(lumbar NEAR/1 pain) 5. Topic=(disc NEAR/1 degeneration) OR Topic=(disc NEAR/1 prolapse) OR Topic=(disc NEAR/1 herniation) 6. #1 OR #2 OR #3 OR #5 OR #5 	<ol style="list-style-type: none"> 7. Topic=(farmer*) OR Topic=("agricultural worker" or "agricultural workers") OR Topic=("farm worker" or "farm workers" or "farm work" or farmworker*) 8. TS=(breeder* or cultivator* or grower* or harvester* or plowman or sower* or tiller* or agronomist*) OR TS=(stockman or stockmen or stockperson or "stock person" or stockpersons or "stock persons") OR TS=(granger* or herdsman or herdsmen or "herds person" or "herds persons" or "herdsperson" or "herdspersons" or agriculturalist* or shepherd*) 9. Topic=(farming or producer* or agriculture or "animal husbandry" or aquaculture or beekeeping or apiculture or dairying or gardening or hydroponics) OR Topic=("sheep shearer" or "sheep shearers" or "livestock worker" or "livestock workers" or "live stock worker" or "live stock workers") OR Topic=(tractor*) 10. #7 or #8 or #9
13. #6 AND #10	

Table 5: Scopus (1823 - present) search strategy.

'Low Back Disorder' search terms	'Farming' search terms
<p>1. ((TITLE-ABS-KEY("low back pain" OR "back pain" OR backache)) OR (TITLE-ABS-KEY(back W/1 (injur* OR disorder* OR pain OR dysfunction* OR problem* OR ache*))) OR ((TITLE-ABS-KEY(lumbosacral region OR sacrococcygeal region OR back OR spine OR coccyx OR "intervertebral disc" OR "lumbar vertebrae" OR sacrum OR "spinal canal" OR "thoracic vertebrae")) AND ((TITLE-ABS-KEY(musculoskeletal W/4 (symptom* OR injur* OR disorder* OR pain OR dysfunction* OR problem* OR disease*))) OR (TITLE-ABS-KEY((orthopedic OR orthopaedic) W/4 (injur* OR problem* OR disorder* OR dysfunction*))) OR (TITLE-ABS-KEY(muscle W/1 strain*))) OR (TITLE-ABS-KEY(sciatica OR lumbago OR dorsalgia OR coccydynia OR discitis OR "facet joints" OR "intervertebral disc" OR arachnoiditis OR "spinal fusion" OR postlaminectomy)) OR ((TITLE-ABS-KEY(hip W/2 pain)) OR (TITLE-ABS-KEY(lumbar PRE/1 pain)) OR (TITLE-ABS-KEY(disc W/1 degeneration)) OR (TITLE-ABS-KEY(disc W/1 prolapse)) OR (TITLE-ABS-KEY(disc W/1 herniation)) OR (TITLE-ABS-KEY(disc W/1 herniation))))</p>	<p>2. ((TITLE-ABS-KEY(farmer* OR "agricultural worker" OR "agricultural workers" OR "farm worker" OR "farm workers" OR farmworker*)) OR (TITLE-ABS-KEY(stockman OR stockmen OR stockperson OR "stock person" OR stockpersons OR "stock persons" OR granger* OR herdsman OR herdsmen OR "herds person" OR "herds persons" OR "herdsperson" OR "herdspersons" OR agriculturalist* OR shepherd*)) OR (TITLE-ABS-KEY(breeder* OR cultivator* OR grower* OR harvester* OR plowman OR sower* OR tiller* OR agronomist*)) OR (TITLE-ABS-KEY(farming OR producer* OR agriculture OR "animal husbandry" OR aquaculture OR beekeeping OR apiculture OR dairying OR gardening OR hydroponics)) OR (TITLE-ABS-KEY("sheep shearer" OR "sheep shearers" OR "livestock worker" OR "livestock workers" OR "live stock worker" OR "live stock workers"))</p>
13. 1 AND 2	

Table 6: Draft screening tool for use at the title and abstract screening stages. Exclusion occur if the answer to any of the questions is no.

Title screening questions (Based solely on the title of the report)	Abstract screening questions (Based solely on the abstract of the report)
1) Does the study deal with LBD? a) No – exclude b) Yes or uncertain - go to step two 2) Does it relate to farming occupations or agricultural work? a) No – exclude b) Yes or uncertain – go to step three 3) Does the study deal with Adults (over 18)? a) No – exclude b) Yes or uncertain – go to step four 4) Does the study deal with Humans? a) No – exclude b) Yes or uncertain – go to step four 5) Does the article represent primary study or a review? (i.e. no letters to the editor, book reviews, published study designs or trial protocols) a) No – exclude b) Yes or uncertain – Include	1) Does the study deal with LBD? a) No – exclude b) Yes or uncertain - go to step two 2) Does it relate to farming occupations or agricultural work? a) No – exclude b) Yes or uncertain – go to step three 3) Does the study deal with Adults (over 18)? a) No – exclude b) Yes or uncertain – go to step four 4) Does the study deal with Humans? a) No – exclude b) Yes or uncertain – go to step four 5) Does the article represent primary study or a review? (i.e. no letters to the editor, book reviews, published study designs or trial protocols) a) No – exclude b) Yes or uncertain – Include

Table 7: Draft screening tool for the full-text review stage. Exclusion occur if the answer to any of the questions is no.

<p style="text-align: center;">Full text screening questions</p> <p style="text-align: center;">(Based solely on the full text of the paper)</p>	
1)	Does the study deal with LBD? a) No – exclude b) Yes or uncertain - go to step 2
2)	Does it relate to farming occupations or agricultural work? a) No – exclude b) Yes or uncertain – go to step 3
3)	Does the case definition of LBD fit our criteria? a) No – exclude, b) Yes - go to step three, c) Uncertain - add to list of questions for discussion and proceed to step 4
4)	Does the study deal with Adults (over 18)? a) No – exclude b) Yes or uncertain – go to step 5
5)	Does the study deal with Humans? a) No – exclude b) Yes or uncertain – go to step 6
6)	Does the article represent primary study or a review? (i.e. no letters to the editor, book reviews, published study designs or trial protocols) a) No – exclude b) Yes– Include c) Yes but uncertain about one or more of steps 1 – 5 –discuss with co-investigators
7)	Does this study assess prevalence or incidence of LBD? a) No – exclude the study from extraction process for research question 1 b) Yes – include the study in extraction process for research question 1
8)	Does this study investigate awkward posture as an exposure? a) No – exclude the study from extraction process for research question 2 b) Yes – include the study in extraction process for research question 2
9)	Does this study use inferential statistics to investigate the association between awkward posture and LBD? a) No – exclude the study from extraction process for research question 3 b) Yes – include the study in extraction process for research question 3

APPENDIX-2: Consent Form



UNIVERSITY OF
SASKATCHEWAN

Participant Consent Form

Project Title: in Saskatchewan Farmers

Researcher(s):

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Purpose(s) and Objective(s) of the Research:

Low back disorders are a common and expensive problem in the general population, and studies show rates of low back disorders are even higher in farmers. Exposures such as vibration from vehicles and machinery, awkward or sustained postures, and manual handling are suspected to be risk factors for low back disorder in farming. We suspect that farmers may have more opportunity to be exposed to these risk factors than non-farmers, but this has never been studied in the types of commodities produced in Saskatchewan. In this study we plan to learn more about:

- How many Saskatchewan farmers have low back pain, how severe it is, and how it affects them

- Farmers' exposure to risk factors like vibration, lifting, and bending
- The types of preventative safety measures farmers use.

Procedures:

- Participation in the farm measurements involves 3 visits to your farm at different times of the year. There are 5 types of measurements we would like to make:
 1. **In-depth interview:** We would like to ask you about your back health, typical work on the farm, and any preventative measures you may have put in place. This will take place only once during the winter visit and is expected to take about 60 minutes. This interview will be audio recorded; you can request to have the recorder turned off at any time.
 2. **Quick exposure questionnaire:** after you complete your work tasks, we would like you to fill in a 4-page questionnaire about what those tasks, postures, lifting, and vehicle use. This will take place during the Winter, Spring, and Fall visits and is expected to take about 10 minutes.
 3. **Vehicle/machinery vibration:** we would like to measure the vibration coming through the seat of any vehicles or machinery you operate on your farm. We will place a sensor on the vehicle seat; you can perform your work as you normally would while the sensor is there. We would like to measure vibration in the Winter, Spring, and Fall.
 4. **Back posture:** We would like to place some sensors on your back to see how your back moves as you perform your regular work tasks. These sensors are small and can be worn under your clothes so that you can perform all your regular work tasks while you wear them. We would like to measure posture in the Winter, Spring, and Fall. Combined with the vibration measurements, the time to set up and remove this equipment is expected to be about 20-30 minutes.
 5. **Observation with a video camera:** We would like to film your work tasks so we can count the number of lifts, carries, pulls, and pushes. We use a camera because often the work happens too fast for us to write everything down, so we need to slow down the video. We have a force meter so that we can determine the weights and push/pull forces of common lifts. This will take place during the Winter, Spring, and Fall visits. Video recording takes place during your regular work tasks, so does not require any additional time.
- Please feel free to ask any questions regarding the procedures and goals of the study or your role.

Funded by: The Saskatchewan Health Research Foundation (SHRF).

Potential Risks:

- The time it takes to set up the equipment could be disruptive. Our research staff will be trained and well-practiced so that we can conduct measurements with as little interruption as possible.
- It is possible that the adhesive tape for the posture sensors may cause itchiness. If this happens, we will discontinue measurement,

Potential Benefits:

- Once complete, we will give you a copy of the overall study results
- We expect that the information gained from this study will be useful in the future studies of injury prevention, which will benefit the health of all people who work in farming.

Compensation:

- You will not be paid to participate in the study. However, as a thank-you and acknowledgment of your participation, we would like to give you a University of Saskatchewan travel mug.

Confidentiality:

- The data collected in this study will be used for the academic thesis projects of graduate students Muhammad Khan and Xiaoke Zeng.
- You have been assigned a study number that will make your study information anonymous. The cover page of the measurement form that has your name, address and telephone number will be stored separately from your test results. That way, it will not be possible to connect your name with any specific responses or results.
- Although the results from this study may be published and presented at conferences, the results will be reported in summary form (i.e. all results combined into an average), so that it will not be possible to identify individuals or locations.

Storage of Data:

- Electronic data (with your personal information removed) will be stored on a password-protected server at the University of Saskatchewan in the care of Dr. Catherine Trask.
- All paper copies of study information will be stored in a locked cabinet inside a locked office at the University of Saskatchewan in the care of Dr. Catherine Trask for at least five years. After this time, paper materials will be destroyed using a secure shredding method.

Right to Withdraw:

Your participation is voluntary and you can answer only those questions that you are comfortable with. You may withdraw from the research project for any reason, at any time without explanation or penalty of any sort.

- Whether you choose to participate or not will have no effect on your membership in the Agricultural Health and Safety Network or how you will be treated.
- Should you wish to withdraw, any data that you have contributed will be destroyed.
- Your right to withdraw data from the study will apply until the results have been analyzed and published. After this date, it is possible that some form of research dissemination will have already occurred and it may not be possible to withdraw your data.

Follow up:

- To obtain results from the study, please contact Dr Catherine Trask or visit the CCHSA website at: <http://www.cchsa-ccssma.usask.ca/>

Questions or Concerns:

- Contact the researcher(s) using the information at the top of page 1;
- This research project has been approved on ethical grounds by the UofS Research Ethics Board on **(insert date)**. Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office ethics.office@usask.ca (306) 966-2975. Out of town participants may call toll-free (888) 966-2975

Your signature below indicates that you have read and understand the description provided; I have had an opportunity to ask questions and my/our questions have been answered. I consent to participate in the research project. A copy of this Consent Form has been given to me for my records.

_____	_____	_____
<i>Name of Participant</i>	<i>Signature</i>	<i>Date</i>

Researcher's Signature

Date

Visually Recorded Images/Data: Participant or parent/guardian to provide initials:

With your permission, we will use video to show students and other researchers what farm work is like. We will not identify you or your farm by name. Even if no names are used, you may be recognizable if visual images are shown as part of the results.

- Photos* of me may be used for: ☐ Student training
☐ Scientific presentations and publications
- Videos* of me may be used for: ☐ Student training
☐ Scientific presentations and publications

A copy of this consent will be left with you, and a copy will be taken by the researcher.

APPENDIX-3: Systematic Review Sensitivity Analysis

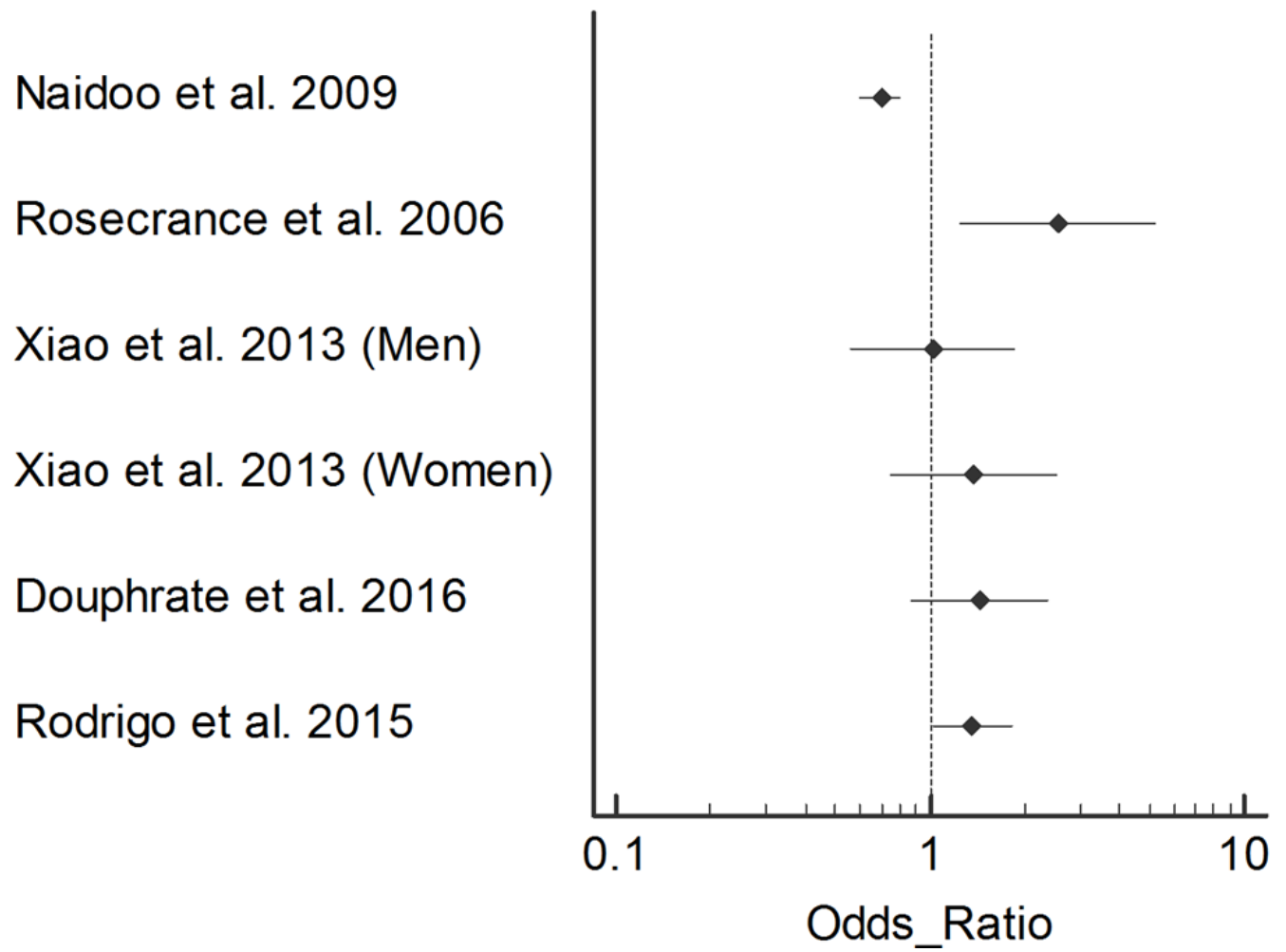


Figure 1. Sensitivity analysis based on only acceptable LBD definitions

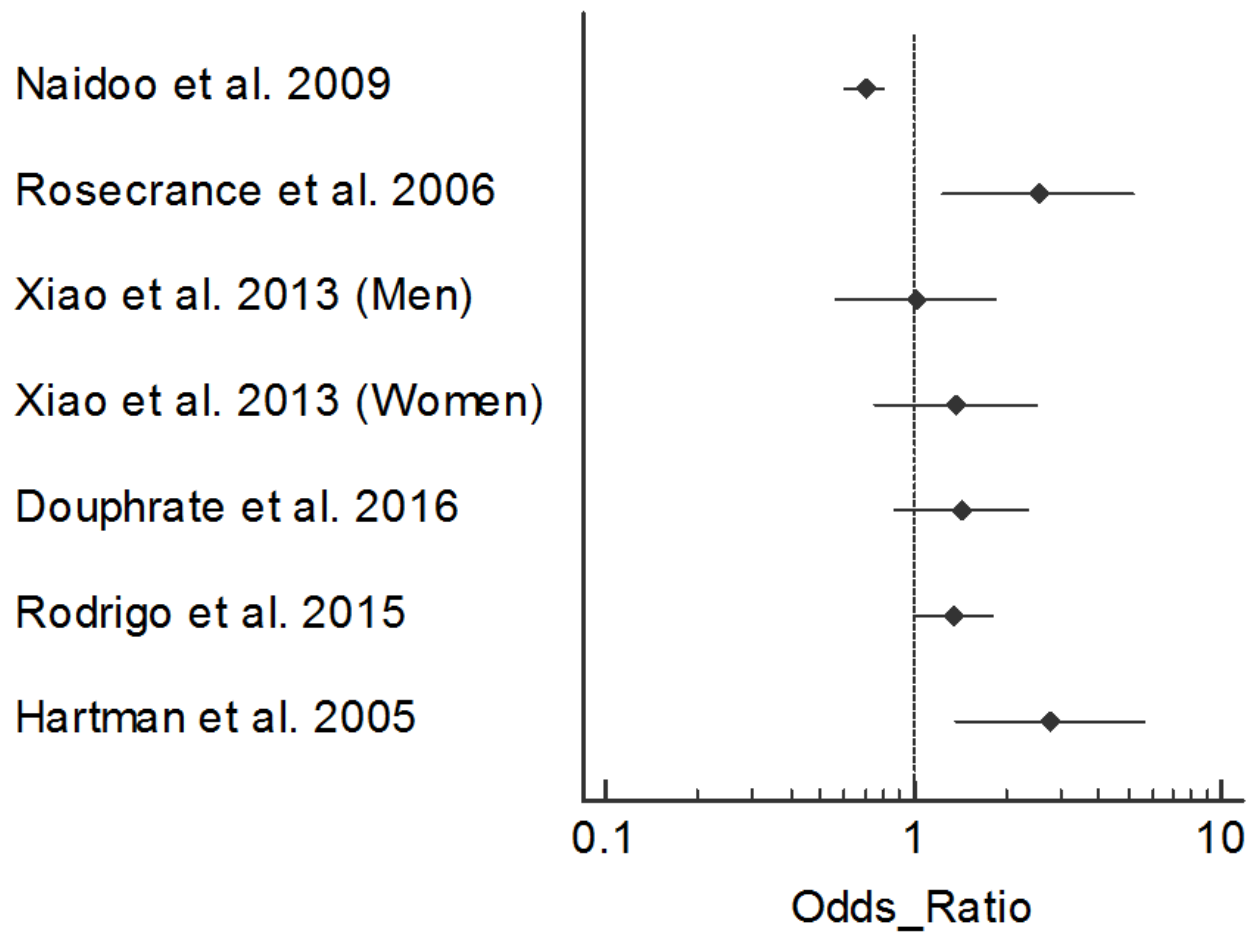


Figure 2. Sensitivity analysis based on only studies that met all the Hoy et al ROB criteria

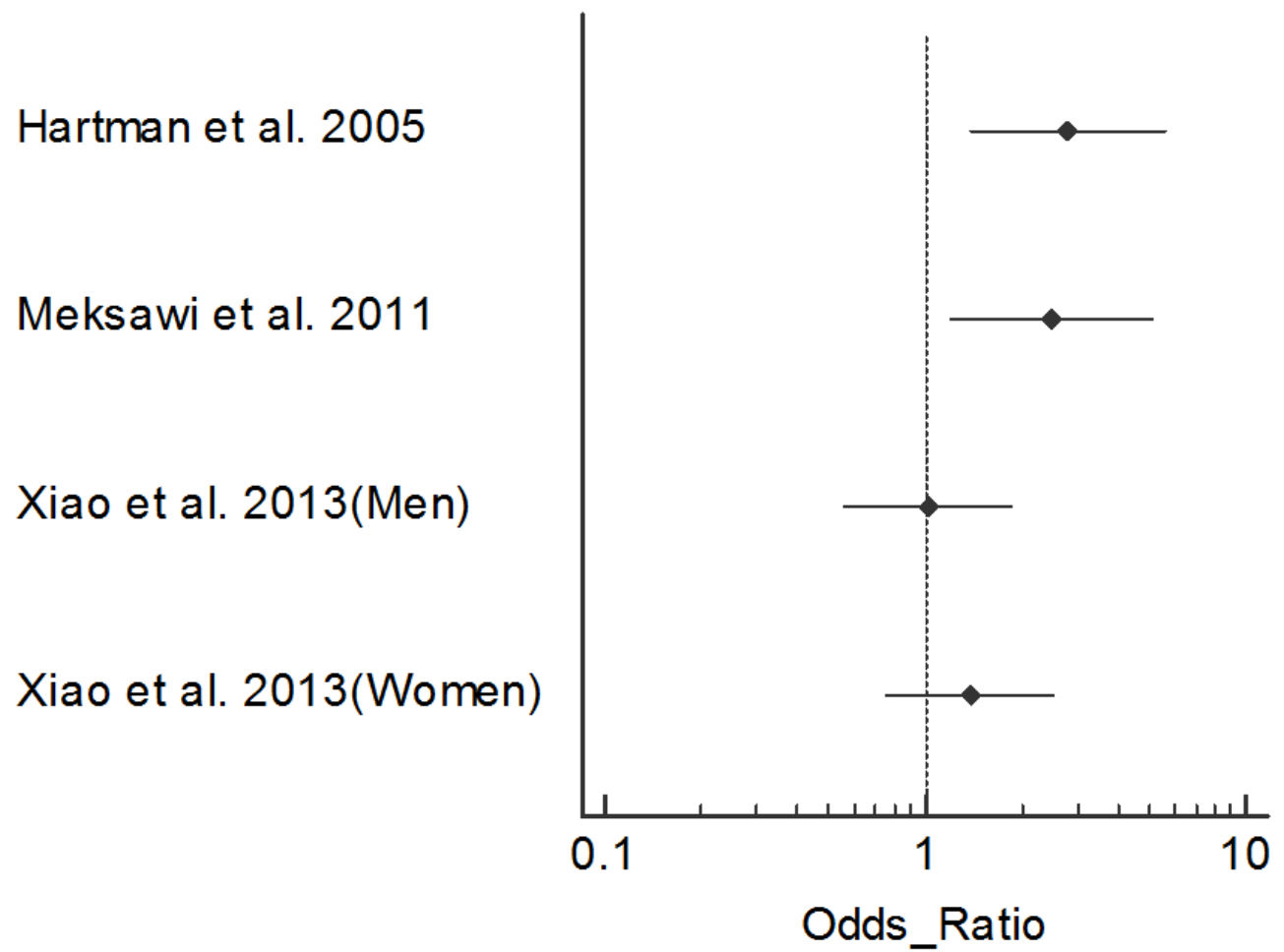


Figure 3. Sensitivity analysis based on study exposure categories

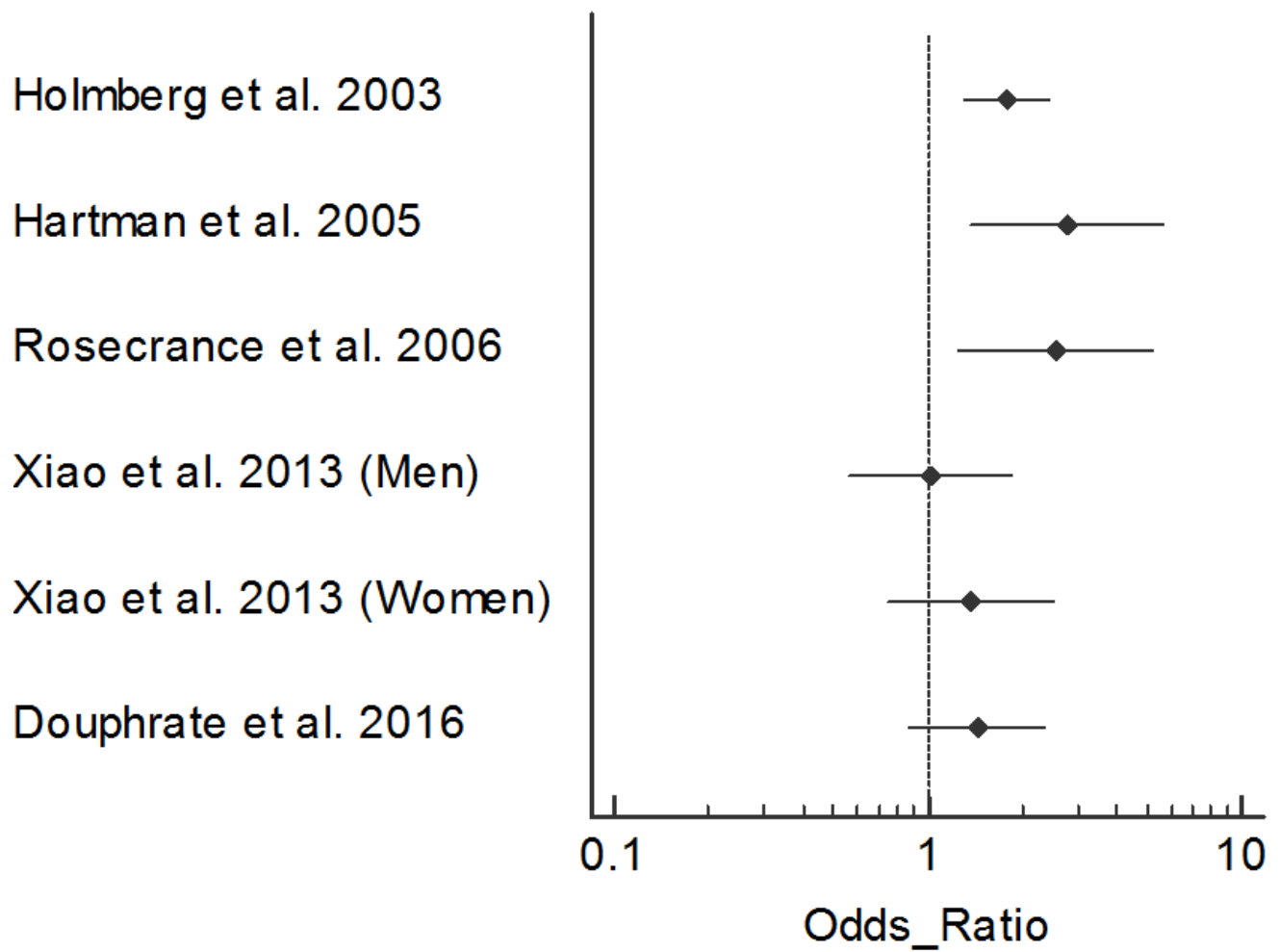


Figure 4. Sensitivity analysis based on study conducted in high income countries